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DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
BUREAU OF MINES
VAN. H. MANNING, DIRECTOR

MELTING BRASS IN A ROCKING ELECTRIC FURNACE

BY

H. W. GILLETT AND A. E. RHOADS

J. T. King
Feb/19

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PREFACE.

It has long been recognized that electric brass melting offers many theoretical advantages, such as saving of zinc, a high quality of product through freedom from contamination of the melt by oxygen and sulphur, the elimination of crucibles, ability to melt large charges, and better and safer working conditions. Commercial experience during the last few years has shown that all these advantages may be attained in practice. Various types of electric furnaces have been devised for brass melting, some of which are suitable only for a rather narrow range of foundry and rolling-mill conditions, or have certain drawbacks that limit their applicability.

In the experimental work of the Bureau of Mines on brass melting, which has been conducted during a period of more than five years, a rocking furnace has been evolved by Dr. Gillett and his associates, which appears fitted to a rather wider variety of conditions than most other furnaces. This furnace has been built in commercial size and submitted to commercial tests, and the results indicate that it not only reduces metal losses, avoids the use of graphite crucibles, and hence the need of ships for importing graphite from Ceylon, but is so economical in use of electric power that no more fuel is required for brass melting, after conversion of the fuel energy into electricity, than if the fuel were used direct in a fuel-fired brass furnace. Not only does the use of the furnace show a large reduction in melting cost at present prices, but it also shows a saving over the melting cost at prewar prices.

Comparison of the cost of melting, on a 10-hour schedule, in the rocking electric furnace and in the coke-fired crucibles of the plant at which the tests were made show that the cost, per ton of charge, for electric power, interest, and depreciation, electrodes, linings, and the heating of ladles is about one-half of the cost, at present prices and present crucible life, of the single item of crucibles for coke fires. Hence under present conditions a huge saving is possible by electric melting. Under normal conditions the saving will be smaller but decided. With 24-hour operation the balance in favor of the electric furnace would be still larger.

The usefulness of such a furnace in the brass industry is evident, and this paper is published in the hope that it may stimulate the use, not only of the rocking furnace but of all other electric furnaces under conditions to which each is adapted, and hasten the savings to the brass melter and the conservation of metal to the country that electric furnaces make possible.

Charles L. Parsons,
Chief Division of Mineral Technology.

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MELTING BRASS IN A ROCKING ELECTRIC FURNACE.

By H. W. GILLETT and A. E. RHOADS.

INTRODUCTION.

In its study of methods for reducing metal losses in the nonferrous metal industry, the Bureau of Mines has conducted a long series of experiments on electric brass melting and collected much data on the experiments of others. Reports bearing on this work that have already been published by the Bureau of Mines are Bulletin 73, "Brass-furnace practice in the United States," and Bulletin 77, "The electric furnace in metallurgical work."

A comprehensive report describing the design and operation of all types of electric brass furnaces and showing their performance in experimental tests on a commercial scale is in course of preparation. However, commercial tests of several new and promising types of furnaces are still under way, the results of which should be included in any general discussion of the subject. For this reason it has seemed desirable to issue a preliminary bulletin giving the data on a type of furnace developed in one stage of the bureau's work.

OBJECT OF REPORT.

The object of this paper is to set forth in detail the possibilities and limitations of a rocking electric brass furnace. The general problem of electric brass furnaces is discussed and various types of furnaces are compared only so far as is necessary for the purpose of this report. Information on such other furnaces as have found commercial use is obtainable from the makers of the various furnaces. Reference to some of the more important articles in scientific and technical publications, dealing with the general subject of electric brass melting and with the performances of various specific types of furnaces, is made herein in order that interested persons may pursue the subject further.

VARYING CONDITIONS A MELTING FURNACE MAY MEET.

A brass furnace—for brevity the term brass is here loosely used to include brass and bronze—may have to meet widely varying conditions, according to the work to be performed. A brass rolling-mill, in general, works with alloys of high zinc content, which are normally made up in large proportion from new metals, and such a mill can, and often does, operate on a 24-hour basis. The tonnage of any given alloy is usually large enough for separate furnaces to be used for melting different alloys. There is a possibility of utilizing furnaces of fairly large capacity in the rolling-mill industry.

Brass foundries vary in size and kind of output from the little jobbing shop, making small quantities of alloys of many different compositions, to the departments of huge manufacturing plants turning out a vast tonnage of a few standard compositions. The type of castings may vary from small intricate patterns, requiring very hot metal, to large castings that are best poured with rather cool metal. The work may be such that night molding is feasible, and operating 24 hours a day is desirable, or be such that operation is practicable only in the daytime. Depending on the nature of the plant and of the work, a furnace may melt the same alloy throughout the year, or may not make two consecutive heats on the same alloy. The alloys may vary from pure copper through bronze, red brass, leaded bearing-metals, half-yellow and half-red brass, yellow brass, and manganese bronze to brazing spelter, or from no zinc to 50 per cent zinc and no lead to 25 per cent or more lead.

Plants refining waste materials and scrap may have as wide a range of alloys as that given in the preceding paragraphs, and in addition their operation may be complicated by the use of very bulky and dirty materials.

Obviously, no single size or type of furnace, whether fuel-fired or electric, can satisfactorily meet all the various conditions encountered in nonferrous melting.[a]

PRESENT NEED FOR ELECTRIC BRASS FURNACES.

Fuel-fired furnaces are divisable into several types, according to the kind of work that is to be done. The two chief classes, disregarding minor subdivisions, are crucible furnaces and open-flame oil furnaces. With the advent of an acute crucible shortage, coupled with a five-fold increase in price and a vast decrease in quality, the use of crucible furnaces has become more and more confined to the production of alloys high in zinc, such as rolling-mill brasses whereas the use of open-flame oil furnaces for making red brasses and bronzes—alloys low in zinc—has markedly increased. That is, the metal losses in melting yellow brass in open-flame oil furnaces have in general been found to overbalance even the present high cost of crucibles.

But even for red brass and bronze, many users still find it undesirable to replace crucible furnaces with types not using crucibles.

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[a] Compare, Clamer, G. H., Melting brass in the induction furnace, Jour. Am. Inst. Metals, vol. 11, 1917. p. 381.

Zinc losses are high in melting yellow brass, even in crucibles, and there is need for furnaces that will eliminate crucible costs and reduce the zinc losses. In melting bronzes the need is for furnaces that will eliminate crucibles and, if possible, do away with the disadvantages of open-flame oil furnaces.

War conditions have greatly accentuated these needs, and have hastened the commercial development, trial, and application of various types of electric brass furnaces, for theoretically these furnaces seem capable of meeting the situation.

THEORETICAL ADVANTAGES OF ELECTRIC BRASS MELTING.

The theoretical advantages of electric brass melting are obvious.[a] They are as follows:

1. Metal losses by oxidation and volatilization may be reduced, because electric furnaces may melt the charge in a nonoxidizing atmosphere and may be tightly closed to prevent volatilization losses.
2. As regards thermal efficiency, a greater proportion of the heat produced in an electric furnace may be utilized than of that in a fuel-fired furnace.
3. The heat input and hence the temperature of the melt may be more closely controlled than in fuel-fired furnaces.
4. Storage and handling of fuel and ashes are eliminated.
5. Metal of "crucible quality" may be produced without the use of crucibles.
6. Working conditions as to health, comfort, and safety of the melters are better than with fuel-fired furnaces.

TYPES OF ELECTRIC BRASS FURNACES COMMERCIALLY TESTED.

General information on the various types of electric furnaces used in the metal industries can be found in the treatises by Stansfield [b]; by Rodenhauser and Schoenawö [c]; in Bulletin 67 [d], and Bulletin 77 [e] of the Bureau of Mines; in the Transactions of the American Electrochemical Society, the Transactions of the Faraday Society, and in the issues of Metallurgical and Chemical Engineering.

Not every type of electric brass furnace meets every melting condition in the industry, nor does it necessarily have all the advantages theoretically possible in an electric furnace. Hence various forms have appeared, designed to meet various conditions.

---

[a] See Roeber, E. F., Manufacture of brass in the electric furnace, Electrochem. and Met. Ind., vol. 3, 1905, p. 4; Clamer, G. H., and Hering, C., The electric furnace for brass melting, Trans. Am. Inst. Metals, vol. 6, 1912, p. 95; Miller, D. D., The electric furnace for heating nonferrous metals, Jour. Am. Inst. Metals, vol. 11, 1917, p. 257.

[b] Stansfield, A., The electric furnace, 1914, 415 pp.

[c] Rödenhauser, W., and Schoenawa, J. trans. by vom Baur, C. H., Electric furnaces in the iron and steel industry, 1917, 419 pp.

[d] Lyon, D. A., and Keeney, R. M., Electric furnaces for making iron and steel, Bull. 67, Bureau of Mines, 1914, 142 pp.

[e] Lyon, D. A., Keeney, R. M., and Cullen, J. F., The electric furnace in metallurgical work, Bull. 77, Bureau of Mines, 1914, 216 pp

HELBERGER FURNACE.

Among the crucible furnaces that have been tested on a commercial scale in the United States is the Helberger,[a] a German crucible tilting furnace of 200-pound capacity, which was tested by the National Cash Register Co., at Dayton, Ohio. The tests showed that the furnace had an excessive power consumption, poor crucible life, and was generally inconvenient and of slight promise.[b]

HOSKINS FURNACE.

A Hoskins furnace [c] with carbon blade resistor and removable crucible, 200-pound capacity, made by the Hoskins Manufacturing Co., was tried by the Commonwealth Edison Co. at the plant of the L. Wolff Manufacturing Co., Chicago.

This furnace showed low metal losses, but the power consumption was high and the crucible and the lining were not very durable. The furnace seemed scarcely applicable under the conditions prevailing at that time.

BAILY FURNACES.

Two Baily crucible furnaces built by the Electric Furnace Co. of America were tried out at the Detroit Copper and Brass Rolling Mills. The first one tested was a tilting furnace. This furnace, because of mechanical defects, never melted enough metal to give any reliable data and appeared of so little promise that no further development of it was made. The second furnace was of the lift-out type, taking eight No. 70 crucibles, each of 200-pound capacity. This furnace also failed, because of thermal inefficiency and low output, and was of such design that when the pots were being pulled the heat from the furnace made the work of handling the furnace almost unbearable.

A tilting noncrucible Baily furnace, single-phase, with a granular resistor, melting about 1,000 pounds per heat, was then designed and has found commercial use. This furnace, which has been described by Baily [d] and by Miller,[e] may be classed as somewhat analogous to a reverberatory furnace. Baily furnaces of this type for brass melting are installed at the works of the Lumen Bearing Co., Buffalo, N. Y.; Baltimore Copper Smelting & Rolling Co., Baltimore, Md.; Bridgeport Brass Co., Bridgeport, Conn.; and the Hays Manufacturing Co., Erie, Pa.

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[a] Helberger, H., U. S. patent No. 932986, Transforming smelting furnace, Aug. 31, 1909, and No. 1023309, Electric furnace, Apr. 16, 1912.

[b] Dorsey, H. G., Tests on electric furnaces for brass foundries; Trans. Am. Inst. Metals, vol. 8, 1914, p. 246.

[c] Marsh, A. L., Electric furnace, U. S. patent 882788, Mar. 24, 1908.

[d] Baily, T. F., Resistance type furnace for melting brass, read before Am. Electrochem. Soc., Oct., 1917, not yet published; Annealing and heat-treating of steel and melting of nonferrous metals in the electric furnace, Met. and Chem. Eng., vol. 17, 1917, p. 91; Baily electric metal melting furnaces, Met. Ind., vol. 15, 1917, p. 399.

[e] Miller, D. D., The electric furnace as a medium for heating nonferrous metals, Jour. Am. Inst. Metals, vol. 11, 1917, p. 257.

This furnace, which is applicable to alloys of any zinc content, reduces metal losses, does away with the use of crucibles, and gives good working conditions. For satisfactory performance, it has to be operated continuously or to be heated empty during all or part of the night. The power consumption is higher than that of various other types of electric brass furnaces operating under a similar time schedule and on similar alloys. The high-power consumption in this type of furnace is due to the fact that most of the transfer of heat from the source, the resistor, to the charge is indirectly by reflection from the roof. The rate of power input per unit of capacity is lower in this type than in most other types because too high a rate means too high a working temperature for both resistor trough and roof. It is customary to install a pyrometer in the roof and to take care not to let the roof get overheated. This type can not be "forced." The power used to supply radiation losses from the walls and the roof is, therefore, a large proportion of the total power supply, and the thermal efficiency is, as in any low-powered furnace, rather low. The furnace does not respond promptly to changes in power input and hence temperature control is much more difficult than in most other types.

GENERAL ELECTRIC FURNACE.

Another furnace, the General Electric, or the Collins-Valentine,[a] a tilting noncrucible furnace of 1,500-pound capacity, of the smothered-arc type, made for one, two, or three phase operation, and having automatic electrode control, is described by Miller;[b] it also may be classed as being of the reverberatory or reflected-heat type. After a period of tests at the plant of the General Electric Co. at Schenectady, N. Y., this furnace has been installed for further tests at the Chicago plant of the Crane Co. This type has an even less direct transfer of heat from the source to the charge than the granular resistor type. The smothered arc allows the use of a higher rate of power input per unit of capacity than does a granular resistor, but the higher rate involves a more severe strain on the roof, which in this type is a weak point.

The furnace is still in the experimental stage and is not yet developed to the point where it is considered ready for general commercial service. This type when successfully developed is theoretically capable of a performance of about the same order as regards power consumption, metal losses, and general applicability as the granular resistor type.

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[a] Valentine, I. R., Electric furnace, U. S. patent 1242275, Oct. 9, 1917.

[b] Miller, D. D., Work cited, p. 274.

SNYDER FURNACE.

Two Snyder furnaces,[a] single-phase, direct-arc type, built by the Industrial Electric Furnace Co., are in use at the plant of the Chicago Bearing Metals Co. for melting bearing bronzes high in lead, but practically free from zinc. The furnaces are of 1-ton capacity each, are running 16 to 24 hours a day, and are efficient as regards power consumption. The metal losses, however, are high, so much lead being volatilized as to make working conditions decidedly bad about the furnaces. A furnace of 600-pound capacity of this make and type, which was tested on high-lead bearing-bronzes, could be kept tightly closed, gave fairly low metal losses, and did not emit harmful fume, but it seems impossible to operate the larger furnaces when closed tight. In the smaller size furnace the volatilization losses from yellow brass ingot containing 25 per cent zinc were so high as to show that this type is entirely unsatisfactory for alloys high in zinc. The power factor of these particular furnaces is very low, though such a furnace can be built with a good power factor. Another Snyder furnace is said to have melted brass of unknown grade at the experimental plant of the Industrial Electric Furnace Co.

FURNACE AT A CANADIAN PLANT.

A furnace of the three-phase direct-arc type has been commercially used at the plant of the Canadian Brake Shoe Co., Sherbrooke, Canada, in melting red brass under a slag of molten glass, but has not been used recently on account of shortage of power. No further details are available as to the performance of this furnace.

FURNACES TESTED BY HANSEN.

Hansen [b] made an experimental heat of copper in a Heroult-type furnace which gave off copper fume and poisoned the workmen. He also made an experimental heat of copper in a Weeks single-phase, indirect-arc zinc furnace.[c] Hansen built a three-phase, indirect-arc furnace of the Stassano type at the General Electric Co. plant at Schenectady, N. Y., which was tried on a commercial scale in melting yellow brass, but proved unsatisfactory because of high zinc losses.

Schmelz [d] gives a brief résumé of a few tests of the Stassano-Petinot furnace, a modification of the Stassano indirect-arc furnace.

---

[a] Snyder, F. T., U. S. patent No. 1100995, Electric furnace, June 23, 1914, and No. 1167026, Electric furnace, Jan. 4, 1916. *See* Miller, D. D., work cited, p. 287.

[b] Hansen, C. A., Copper poisoning: Met. and Chem. Eng., vol. 9, 1911, p. 67.

[c] Hansen, C. A., Electric melting of copper and brass, Trans. Am. Inst. Metals, vol. 6, 1912, p. 110.

[d] Schmelz, E. M., Electric furnace for medium temperatures; Trans. Am. Inst. Metals, vol. 8, 1914, p. 261.

RENNERFELT FURNACE.

The only furnace of the ordinary indirect-arc type known to be in commercial use for brass melting in May, 1918, is the Rennerfelt,[a] which is built for two-phase operation and has three electrodes.

There are two 1-ton Rennerfelt furnaces at the plant of the Chicago Bearing Metals Co. that are melting leaded bearing-bronze; a ½-ton furnace at the Philadelphia Mint, melting copper and nickel coinage alloys; and an 800-pound furnace at the Gerline brass foundry, Kalamazoo, Mich., melting Monel metal and red brass.

According to the users and the manufacturers, this type of furnace is satisfactory only for alloys containing not more than about 20 per cent zinc, because with a zinc content higher than 20 per cent the volatilization loss is too large. Even with alloys containing about 20 per cent zinc content some mechanical difficulty is caused by the electrodes sticking, through condensation of zinc vapor around them.

With alloys high in lead the furnace, if kept tightly closed, makes little fume, the working conditions are better and safer, and the metal losses are lower than with furnaces of the direct arc type. However, sticking of the electrodes from condensation of metal vapor, probably lead and antimony, and from deposition of metallic oxides about them, caused electrode breakage, so that the electrode coolers were removed from the furnaces at Chicago and the furnaces were operated with a large clearance about the electrodes, through which much metal vapor is lost, causing poor working conditions. The electrode consumption was greatly increased.

The power consumption in this type, especially in the larger sizes and with 16 or 24 hour operation, is reasonably low. The furnaces work very smoothly when melting alloys that do not contain volatile metals like zinc or lead in too great amount.

BENNETT FURNACE.

A three-phase furnace, known as the Bennett, which is probably of about 750-pounds capacity, has been built at the plant of the Scovill Manufacturing Co., Waterbury, Conn. This furnace is built on lines somewhat similar to a direct-arc furnace, but operates by means of automatic electrode control at a voltage, between the electrode and the bath, too low for a true arc to form, the heat being generated by a sort of contact resistance. The furnace has melted a large tonnage of yellow brass, but is still being developed and its operation is as yet experimental or only semicommercial. It is said to show low metal losses, and a reasonable power consumption.

The engineers of the Scovill company made thorough tests of granular resistor, indirect arc, "pinch effect," and various other types of brass furnaces before choosing the contact-resistance type as most promising for rolling-mill use in melting alloys high in zinc.

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[a] Rennerfelt, I., Electric furnace, U. S. patent 1076518, Oct. 21, 1913.

As this furnace is the outgrowth of a long series of large-scale experiments competently directed, it is to be regretted that no actual data on the performance of the furnace, or even of the unsuccessful experiments with other types has been made public.

A furnace of a somewhat similar type is in use in Germany[a] in melting ferromanganese, the manganese in which is somewhat volatile, though not so much so as zinc in brass.

HERING FURNACE.

The Hering "pinch effect" furnace [b] was tried out thoroughly and on a large scale by the Ajax Metal Co., Philadelphia, Pa., the National Cash Register Co., Dayton, Ohio, and the Scovill Manufacturing Co., Waterbury, Conn., in two-phase and three-phase form. These furnaces poured about 750 pounds a heat.

Tests were made with the furnace, as originally designed, at the plants of all the companies mentioned, also many modifications of it were tested at the Ajax plant. The results were so discouraging that the furnace was abandoned by all these experimenters, chiefly because of the high heat losses in the water-cooling of the metallic electrodes, and mechanical troubles. Some difficulty was found in heating yellow brass of high zinc content hot enough for rolling-mill use, on account of evolution of zinc vapor in the resistor tubes. The furnace showed low metal losses, and its performance indicated that the circulation set up by the "pinch effect" was a desirable feature.

It was obvious in the tests of the Hering furnace that many of the mechanical troubles in that type could be eliminated, and most of the good features retained, if the resistor tubes could be replaced with a resistor loop, thus making an induction furnace. Induction furnaces of the ordinary types used in steel melting, such as the Colby-Kjellin, Frick, Röchling-Rödenhauser, and similar furnaces,[c] are not applicable to the melting of alloys of high electrical conductivity, such as brass, bronze, and the aluminum alloys, although they are in use for melting nickel and its alloys, which have electrical resistances of the order of that of iron. If one attempts to melt copper or brass in an induction furnace with the secondary ring horizontal, the high current required (by the low resistance) in introducing sufficient power to melt the metal is above the working limit[a] of current of the molten conductor. As a result the "pinch" force, which was usefully employed in the Hering furnace, causes the metal to separate in the ring and the flow of current stops.

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[a] Schemmann, W. and Bronn, J., Electric furnace, U. S. patent No. 1056456, Mar. 18, 1913. Rodenhauser, W., Ferromangan als Desoxydation Mittel, 1915, p. 26.

[b] Hering, C., Electric furnace, U. S. patent No. 988936, Apr. 9, 1911; and No. 999720, Aug. 1, 1914. Hering, C., A new type of electric furnace, Trans. Am. Electrochem. Soc., vol. 19, 1911, pp. 255–272. Clamer, G. H., The Hering electric furnace for commercial brass melting, Trans. Am. Inst. Metals, vol. 7, 1913, p. 350. Clamer, G. H. and Hering, C., Electric brass melting, Trans. Am. Inst. Metals, vol. 8 1914, p. 270.

[c] See Rödenhauser, W. and Schoenawa, J., Trans. by vom Baur, C. H., Electric furnaces in the iron and steel industry, 1917, p. 172.

AJAX-WYATT FURNACE.

In vertical-ring induction furnaces, where the secondary ring is in the form of a loop below a pool of molten metal, the hydraulic head of the molten metal opposes the "pinch" force and may be made high enough to prevent rupture. The Ajax-Wyatt[b] furnace is of this type. This furnace, built in 300 and 600 pound sizes, is in commercial use at the Ajax Metal Co. plant, Philadelphia, Pa., several of the furnaces being used there. Two furnaces of the 600-pound size are in use at the American Brass Co. plant, Waterbury, Conn., and 28 furnaces of the 300-pound size at the Bridgeport Brass Co. plant, Bridgeport, Conn. All these furnaces are melting alloys high in zinc and low in lead. They give very low metal losses, and the rapid circulation of metal due to the pinch force, to thermal effect, and to motor effect, causes a stirring and mixing that produces exceptionally homogeneous alloys. So far the Ajax-Wyatt furnace has been built only for single-phase current and in these comparatively small sizes. The power factor, in these sizes, is satisfactory. The power consumption is extremely low, as would be expected, for the heat is generated in the metal itself.

The drawbacks to this type are as follows: The furnace has to be started with a charge of previously melted metal, which causes difficulty in changing from one alloy to another, and necessitates operating 24 hours a day or using enough power on the furnace at night to keep the metal in the resistor loop molten; the furnace lining, in the shape required by the furnace design, will not withstand alloys that contain more than 3 per cent lead.

FOLEY FURNACE.

A vertical-ring, induction furnace of somewhat similar design is built by Charles B. Foley. A Foley single-phase furnace of 1,000-pound capacity has been in experimental operation at the Bristol Brass Co. plant, Bristol, Conn., and three 3,000-pound furnaces are being constructed there. The experimental furnace has operated with 2,200 volts on the furnace primary, which the writers consider unsafe, but Mr. Foley states that it can be built with 440 or 220 volts on the furnace primary. The power factor of the large furnaces is expected to be rather low, though probably better than in horizontal-ring, induction, steel furnaces of similar size. The Ajax-Wyatt and the Foley furnaces differ distinctly in design and in underlying principles, but their metal losses and power consumption will be about the same. There has been less actual melting done in the Foley furnaces than in the Ajax-Wyatt, and much less data is available on them. The theoretical advantages and the operating drawbacks are about the same for both types.

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[a] Hering, C., A practical limitation of resistance furnaces, the "pinch" phenomenon; Trans. Am. Electrochem. Soc., vol. 11, 1907, p. 329; vol. 15, 1909, p. 255, discussion by Fitzgerald, F. A. J., p. 278.

[b] Wyatt, J. R., Induction furnace, U. S. patent 1201671, Oct. 17, 1916, and Nos. 1235628, 1235629, 1235630, Aug. 7, 1917. Clamer, G. H., Melting brass in the induction furnace, Jour Am. Inst. Metals, vol. 11, 1917, p. 381.

NORTHRUP FURNACE.

Realizing the limitations of the vertical-ring, induction type, the Ajax Metal Co. is now developing the Northrup furnace,[a] made by the Pyro-electric Instrument Co.; this is of the eddy-current induction type and does not require a ring-shaped secondary. When first developed, the furnace used oscillating current at very high voltages and frequency, instead of alternating current. Later developments indicate that it can be designed to run on 100 volts. The use of condensers or of a special generator is required to give oscillating current. A 60-kilowatt tapping furnace is now under test. This offers the same advantage as the vertical-ring induction furnace in that the heat is generated in the metal itself, with consequent low power consumption, and should be more flexible—that is, should be readily operated on a 10-hour or shorter schedule and should readily permit changes from one alloy to another. The furnace has a very high power factor and is built to take two-phase current.

Theoretically this type of furnace is promising, although as long as condensers are used the cost of construction may be rather expensive. The furnace should give low metal losses. Development has not progressed far enough to show whether mechanical difficulties of construction will limit the furnace to comparatively small capacities. The furnace will probably be developed at least far enough to be available for small jobbing foundries where no other type of electric brass furnace so far developed seems to meet the conditions as well as this type might.

REVIEW OF THE TYPES OF FURNACES TESTED.

In the United States four electric brass furnaces, the Ajax-Wyatt, the Baily, the Rennerfelt, and the Snyder, besides the rocking furnace described herein, are on the market and are in actual commercial use, and three, the Foley, General Electric, and Northrup furnaces, are undergoing commercial tests.

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[a] Northrup, E. F., Production of high temperature and its measurement, Met. and Chem. Eng., vol. 17, 1917, p. 685.

A large number of other furnaces, including various types not mentioned in the preceding paragraphs, have been tried on a purely experimental scale; many others have been patented or suggested but not tried; comment on these is withheld from lack of space.

NECESSITY FOR CAREFUL CORRELATION IN COMPARING FURNACE DATA.

Much data on the performance of most of the furnaces specifically mentioned, including power consumption, metal losses, electrode consumption, output, and other factors, is at hand, but would require too much space to be given here. The power consumption, for example, depends so much on the nature of the charge, the temperature at which the metal is poured, the capacity of the furnace, the working period—whether the furnace is operated 24 hours daily, 10 hours with some heating at night, or 10 hours with no night heating—the speed of charging and pouring, rate of power input, etc., that any set of figures for power consumption may be, unless all the conditions are given in detail, not only inaccurate, but strongly misleading.

Similarly, figures for metal losses, expressed as percentages, in tests of different furnaces are not directly comparable, but must be carefully examined. For example, a 2 per cent metal loss, given as the performance of some one furnace on a certain alloy, might refer to the net loss on clean ingot metal, after the amount of metal recoverable from dross, spillings, and soakage into furnace linings had been deducted. On the other hand, a 5 per cent metal loss, shown by another furnace working on a similar alloy, may refer to the gross loss, with no deduction for recoverable metal, in melting a charge of dirty, oily borings. As a result, this 5 per cent loss might really mean a much better performance than the 2 per cent loss shown by the other furnace, owing to the difference in conditions and method of calculation.

Therefore, in comparing different electric brass furnaces to determine their suitability for a given set of conditions, it is necessary to be sure that figures given in published reports of tests or in makers' guarantees refer to exactly similar conditions, or else to make suitable allowances for the variations.

ADVANTAGES AND LIMITATIONS OF SPECIFIC TYPES OF FURNACES.

The direct-arc type of furnace is applicable to the melting of pure copper, true bronze, and red brass. Its use is confined to alloys low in zinc, and it should not be used for alloys high in lead, because of the danger of poisoning from the volatilized lead. Such a furnace can be built in large capacities, and three-phase current can be used. It can be operated on a 10-hour schedule without night heating.

The indirect-arc type has about the same advantages and disadvantages as the direct arc, but will handle alloys higher in volatile constituents than the direct arc type.

The contact-resistance type should theoretically be suitable for all alloys and for 10-hour operation. Unfortunately, the only furnace of this type in use for brass melting is available only to the firm now developing it.

The reflected-heat type—which is in two forms, the granular-resistor and the smothered arc—should be applicable to all alloys, but on account of the indirect way in which the heat is applied will be only moderately efficient in power consumption even when working 24 hours a day. On 10-hour operation the heating of the empty furnace at night will be desirable, if not necessary, in order to get a reasonable output in the daytime. This type of furnace will not give as close control of temperature as the other types. It will be at its best in rather large sizes.

The vertical-ring, induction type is especially applicable to alloys high in zinc. Theoretically it can be used for all alloys, but it has not been developed or tested for making bronze. Such a furnace is not suitable for use at plants where one furnace must make successive heats on alloys of different composition. It has a high efficiency when working 24 hours daily on one alloy, and if operated only in the daytime its efficiency may overbalance the cost of using enough power at night to keep the contents molten. It works well in rather small sizes, but its applicability in large sizes has not yet been proved.

The eddy-current type of furnace should be efficient, applicable to all alloys, and operable on a 10-hour basis, but the actual performance and the possibilities as to size have yet to be determined.

Those rolling mills that can use one furnace for melting one alloy high in zinc 24 hours a day can gain the advantages of electric melting by using a furnace of the vertical-ring, induction type. A foundry making only red brass or bronze could use a direct or indirect arc type. If alloys containing up to about 20 per cent zinc are also to be melted, the direct-arc type would not serve, and if alloys still higher in zinc are to be melted, neither of these arc furnaces would serve, and the reflected-heat type might be used. Where continuous operation is not possible and the power cost is high, the lower thermal efficiency of this type would be a drawback. The eddy-current type may meet these conditions when it is developed, but for the moment there seems to be a gap not completely filled by any type of electric furnace that is immediately available. The rocking furnace developed and tested by the Bureau of Mines may perhaps help fill this gap.

HISTORY OF THE DEVELOPMENT OF THE ROCKING ELECTRIC FURNACE.

When the Bureau of Mines found, by its own tests and by the experience of others, that the direct and indirect-arc types of furnace used for steel were not suited for melting alloys high in zinc, some modification was sought that would partly or wholly remedy this limitation. As the indirect-arc type is already applicable to alloys higher in zinc content than the direct arc type is, it was obvious that attention should first be directed to the indirect type.

The high metal loss in the ordinary indirect-arc furnace is due to the fact that the source of heat, the arc, is above the metal, which is heated both by direct radiation from the arc and by heat reflected downward from the roof. The loss of zinc while the charge is melting is small, as the metal runs down through the charge to the bottom of the hearth. After the charge is molten, during the period of superheating to pouring temperature, there is little circulation within the melt, as hot metal is lighter than colder metal and tends to stay on top. If the rate of heat input is at all rapid, as is needful for thermal efficiency, heat is supplied to the surface of the molten metal faster than it is transmitted to the interior of the mass and a highly superheated surface layer results. Thus the top reaches the boiling point of zinc in yellow brass, while the bottom is scarcely above the melting point, and the average temperature of the bath is not high enough for satisfactory pouring. In brasses of 20 to 40 per cent zinc content, the boiling points are only 25 to 50° C. (50° to 100° F.) above the necessary pouring temperatures.[a]

If the furnace is not kept tightly closed, zinc vapor is continually lost. If the furnace is tightly sealed, pressure builds up within the furnace and may blow out the door or the roof at a weak point. Or, if the pressure is not relieved before the spout is opened for pouring, a long hissing stream of zinc vapor will shoot out, burning as it reaches the air. On account of the mechanical troubles due to this building up of pressure, and the loss of zinc, the indirect-arc furnace is not satisfactory for alloys high in zinc.

The obvious means of avoiding superheating of the surface layer, with its attendant troubles, is to stir the melt so vigorously that the temperature of the metal is practically uniform. This result might be accomplished by putting Hering resistor tubes or a vertical-ring induction loop below the melt, and utilizing the stirring action of this circuit to mix the metal. However, the use of two separate electrical circuits would be cumbersome.

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[a] Gillett, H. W., Brass furnace practice in the United States, Bull. 73, Bureau of Mines, 1914, p. 129; Johnston, J., The volatility of the constituents of brass, Jour. Am. Inst. Metals, vol. 12, 1918, p. 15.

A mechanical stirring device might be used, such as has been suggested by Johnson,[a] but great difficulty may be expected in maintaining such a device.

Stirring by the principle of the cement mixer seemed the most feasible method. Rotary fuel-fired furnaces are common, the rotary cement kiln being the most noteworthy example. Open-flame oil furnaces for brass melting are often rocked back and forth by hand during the last part of a heat to mix the charge and hasten melting. Very recently an open-flame oil furnace[b] mechanically revolved during the process of melting has been placed on the market.

Various types of electric furnaces that may be rotated during part or all of the heat have been proposed Carrere[c] suggests a cylindrical furnace with non-rotatable ends, the body being rotated and heat being generated either in the walls or by a central arc.

Von Ischewsky[d] shows a rotating furnace in which heat is generated in the walls of the furnace.

Thompson and Fitzgerald[e] describe revolving furnaces in which heat is generated in a central resistor. Weeks[f] and Imbert[g] describe practically identical furnaces for zinc smelting. A central arc is used and the furnaces are capable of rotation during the melting, but the ends do not rotate.

The Stassano steel furnace[h] may be, and some installations[i] have been, provided with a mechanism by which the furnace as a whole is oscillated by rotating about a slightly inclined vertical axis. This, however, will not produce as rapid mixing as seems desirable.

The Rennerfelt furnace may be, according to the patent,[j] provided with a projection in the hearth designed to stir the charge when the furnace is rotated in one direction or the other. However, so far as is known, no Rennerfelt furnace has been so constructed, nor has systematic rocking of the furnace during melting been suggested.

On account of the way the electrodes must enter the furnace in the multiphase Stassano and Rennerfelt furnaces, complete rotation, or even oscillation, of the furnace is impracticable.

In order to prevent the roof getting hotter than the melt, with consequent reflection of heat from the roof in addition to radiation from the arc, the unwashed part of the roof should be as small as possible.

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[a] Johnson, W. M., Process of making alloy castings, U. S. patent 1243416, Oct. 16, 1917.

[b] Editorial, A noncrucible, revolving, tilting metal-melting furnace: Metal Ind., vol. 16, 1917, p. 38.

[c] Carrere, J. M., Electric furnace, U. S. patent 726860, May 5, 1903.

[d] Von Ischewsky, B., Electric furnace, U. S. patent 847003, Mar. 12, 1907.

[e] Thompson, J., and Fitzgerald, F. A. J., Electric furnace, U. S. patent 950878, Mar. 1, 1910. Thompson, J., Electric furnace, U. S. patent 950880, Mar. 1, 1910.

[f] Weeks, C. A., Electric furnace, U. S. patent 949511, Aug. 6, 1912.

[g] Imbert, A. H., German patent 219515, class 21h, group 8, Mar. 1, 1910.

[h] Stassano, E., Electric furnace, U. S. patent No. 799105, Sept. 12, 1905; No. 1024657, Apr. 30, 1912; No. 1059499, Apr. 22, 1913; No. 1093494, Apr. 14, 1914; No. 1105859, Aug. 4, 1914.

[i] Lyon, D. A., and Keeney, R. M., Electric furnaces for making iron and steel, Bull. 67, Bureau of Mines, 1914, p. 82.

[j] Rennerfelt, J., Electric furnace, U. S. patent 1076518, Oct. 21, 1913.

Hence a cylindrical furnace lying approximately horizontal with the electrodes entering at the ends seemed the most promising form, although on account of the limited space in the ends of any except a large furnace, of, say, 2-ton capacity, a single-phase arc is required and the electrical advantage of multiphase operation is lost.

Of the furnaces mentioned, only the Carrere and the Weeks come anywhere near meeting the conditions imposed. These both have stationary ends and a revolving body, a construction that involves many difficulties in maintaining a gas-tight seal over so large a joint, and in sealing the charging door to prevent leakage of metal when the furnace is revolved. The charging door, on account of lack of space on the ends, above the melt, must be placed on the circumference of the drum.

No account of any actual experiments with the Carrere furnace has been found in the literature. The Weeks zinc furnace, as has been previously stated, was tested by Hansen at the General Electric Co. plant at Schenectady, N. Y., for zinc smelting; also a couple of heats of copper were made in it. The patent specifications for the Weeks furnace make mention of revolving the body of the furnace to interchange the roof and hearth, the advantage being in "uniformly wearing the lining and applying substantially all the heat to the contents," but in a published description of the furnace Weeks [a] makes no mention of revolving the furnace or of the effect of stirring on metal losses. He assumes a figure for metal losses on yellow brass, but it is not based on any experiments.

Hansen,[b] in describing the Weeks zinc furnace, says:

> The drum was mounted on rollers which could be motor driven. * * * The heat was supplied by radiation from an arc and the rotation of the furnace body was intended to equalize temperature of the furnace lining by periodically bringing all the parts of it in contact with the charge. Incidentally, thorough mixture of the charge would be secured by this rotation. The copper-melting experiments were of purely secondary consideration to Mr. Weeks * * *.

Hansen states [c] that in melting zinc with this furnace the electrodes become soldered in place by condensed zinc and could not be adjusted to regulate the arc. Mr. Weeks has informed one of the writers that the furnace, though designed to rotate, was not rotated in the copper-melting experiments. No experiments were made with brass, and the effect of stirring on the superheating of the surface of the melt and on loss of zinc was evidently not impressed on Hansen by the few experiments that were made, for, instead of continuing to experiment with the Weeks furnace, Hansen built a three-phase Stassano-type furnace, which was tested on yellow brass borings at the Schenectady plant. Mr. E. L. Crosby, who witnessed the test, states that the pressure of zinc vapor was so high that the furnace could not be kept tight, and the metal loss was excessive. The experiments with that furnace were abandoned, and the present General Electric brass furnace, which does not provide for mechanical stirring, was designed.

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[a] Weeks, C. A., Melting nonferrous metals in an electric furnace: Met. and Chem. Eng., vol. 9, 1911, p. 363.

[b] Hansen, C. A., Electric melting of copper and brass: Trans. Am. Inst. Metals, vol. 6, 1912, p. 110.

[c] Hansen, C. A., work quoted, p. 126.

Thus there was nothing in patent, or technical literature, on any known tests to show whether rocking an indirect arc furnace could be made to stir the metal sufficiently, or how such a furnace had best be constructed. Nothing had been done with the Weeks zinc furnace since the Schenectady tests in 1910, and, so far as known, no commercial firm was contemplating tests of such a type of furnace. Therefore, it was decided to construct and test a small-scale furnace of this type in the Bureau of Mines laboratory in order that no type that seemed, theoretically, at all feasible should be overlooked.

THEORETICAL ADVANTAGES OF A ROCKING FURNACE.

If the metal losses could be reduced enough below those of fuel-fired practice, the indirect-arc furnace would be promising, for it has many advantages, has been used commercially in steel making and for various other metallurgical purposes, and much is known about its behavior. There is more accumulated knowledge on this type of electric furnace than on any other, except the direct-arc furnace.

Indirect-arc furnaces, for a given power input, take higher voltages and lower currents than resistance or induction furnaces, and smaller transformers, leads, etc., can be used. The temperature is susceptible of considerable regulation by altering the length of the arc—that is, the arc can be regulated inside the furnace.

Such furnaces can be built and operated on a large scale, for 2-ton Stassano furnaces and 3-ton Rennerfelt furnaces are in use for melting steel. The question of size is highly important to rolling mills working on yellow brass, where, in general, 200-pound charges in crucible furnaces are used, although the output of the mills is tremendous. If the metal losses of large fuel-fired non-crucible furnaces did not overbalance their greater fuel economy and lower labor costs, the rolling mills would use the larger furnaces.

With a molten charge, the constant rotation of an indirect arc furnace should have the following advantages:

1. The charge would be thoroughly mixed and overheating of the surface prevented, thus giving a well-mixed alloy, desirable in brass melting, and preventing loss of zinc by sudden volatilization when the furnace is opened.

2. By washing the walls with the charge the heat that the walls have absorbed from the arc by radiation will largely be given up to

the metal, instead of passing out through the walls; that is, such a furnace should have a higher power efficiency than a stationary indirect-arc furnace tilted only to pour. Its efficiency should be higher than that of the reflected-heat type of resistor or smothered-arc furnaces, should probably be slightly higher than that of direct-arc furnaces, and should be second only to that of induction furnaces.

3. The walls, being washed by the molten bath, can not become much hotter than the metal itself; this helps to prolong the life of the lining and to lower the repair costs. With arc heating, the electrodes can be replaced at once with the furnace hot.

Cheaper refractories and those with a lower heat conductivity can be used than in furnaces where the roof or walls get very hot although the use of low-grade refractories will not, in the long run, be advisable.

EXPERIMENTS WITH LABORATORY ROCKING FURNACE.

CONSTRUCTION OF FURNACE.

An ether drum provided with two heavy hoops on which to roll it was used for the furnace shell. The diameter of the shell was not large enough to permit a proper thickness of lining, but it was thought that the furnace should give results for metal losses that would be representative, even though the power-consumption figures might not be. As metal loss is of first importance in determining whether such a furnace will be practicable for commercial work, the available equipment was deemed sufficient for the purpose without entailing much expense in building the furnace.

The furnace as constructed is shown in Plate I. The drum was 22 inches in outside diameter and 32 inches long. The ends were taken off and lined with 10 inches of ordinary fire brick, each end having a central hole 2 inches in diameter for the electrodes. The body of the furnace was lined with circular fire-clay tile 3 inches thick, set in fire clay, and coated inside with $\frac{1}{2}$ inch of No. 30 high-temperature asbestos cement. In later tests this $\frac{1}{2}$-inch lining was replaced with $\frac{1}{4}$ inch of a mixture of fire clay and graphite, such as is used for making crucibles.

A charging hole and pouring spout 5 inches by 4 inches in size was made in the body of the furnace.

Three iron bars bolted to the ends of the shell on each side supported an electrode rest made of asbestos board, which insulated the electrode from the shell.

Graphite electrodes 2 inches in diameter and 40 inches long, when new, were used.

The leads were flexible cables provided with lugs which were clamped to flat places cut on the electrodes, to avoid the cost of special holders. In later tests connection was made by passing flexible copper strips directly around the electrode and clamping them to it without cutting flat places. The electrodes were not water cooled in the first experiments.

Means for rotating the furnace was provided by making a double track from angle irons, along which the iron bands, or heavy, rail-like hoops, on the drum could roll. Spokes projected from each end of the furnace, with which it could be rolled by hand backward and forward along the track.

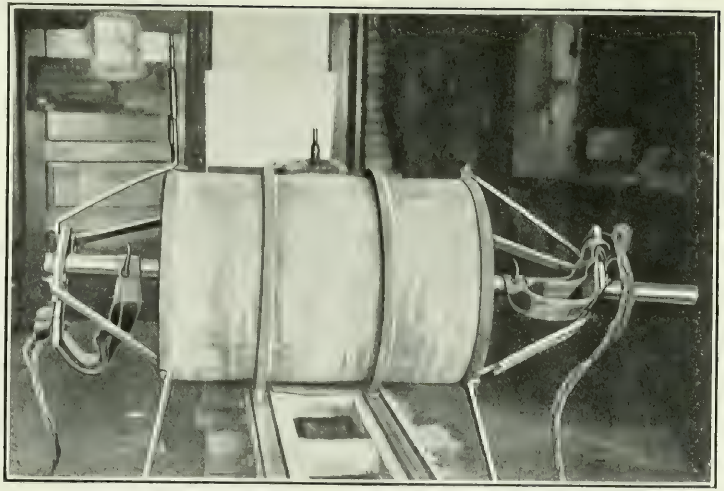
The track was set on brick piers. A long car, on which the ingot molds were set, ran on another track placed between the piers and beneath the elevated track for the furnace. In this way the melt could be poured directly into the molds. The furnace track took up so much room that pouring into a ladle and thence into molds would hardly have been possible in the small laboratory, because of all the other apparatus already in place in it. This pouring arrangement saved the trouble of preheating a ladle and eliminated much work in pouring.

The apparatus for rolling the furnace on the track by hand was cheaply constructed, whereas mounting on trunnions or on rollers would have been costly. The leads either lay along the floor on each side of the track or were suspended from above with enough slack in them to permit the furnace being rolled as far as desired. They were kept from touching the iron bars holding the electrode supports by the asbestos-board insulation on the bars.

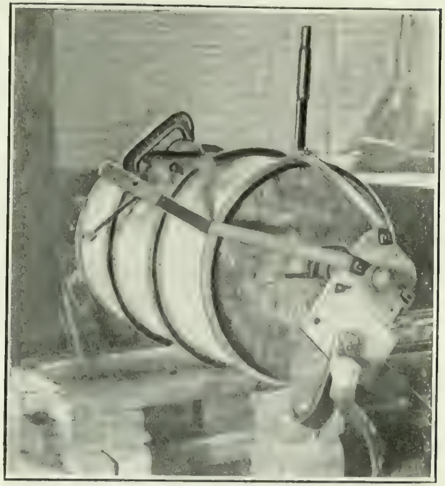
The electrodes fitted quite tightly into the holes through the ends of the furnace, but could be adjusted by hand to start and control the arc. The fire-brick plug used for stopping the charging hole and pouring spout was held in place with an iron bar, which passed through loops fastened to the shell on either side of the hole. Each time after the door was opened the joint between the door and the spout was luted with fire clay. The voltage was 50 to 75 volts, and the current was 500 to 700 amperes, the usual power input being about 30 kilowatts. The power factor averaged 80 to 90, being above 85 during most of any heat.

TESTS ON RED AND YELLOW BRASS.

After the furnace had been thoroughly dried a series of melting tests were begun. The conditions of each individual test and the results obtained are set forth in the following pages. The numbers refer to the laboratory numbers of the tests.



A. LABORATORY ROCKING FURNACE, SIDE VIEW.



B. LABORATORY ROCKING FURNACE, END VIEW.

HEATS WITH INGOT METAL.

HEAT L1.

The cold furnace was preheated 40 minutes, 22 kilowatt-hours being used. Then 65.75 pounds of 2:1 yellow brass ingot was charged. The arc was then run 20 minutes, using 11.5 kilowatt-hours. The furnace was not rocked, as melting was not supposed to have begun. However, on opening the furnace, when the metal was at 1,075° C., zinc vapor shot out with a hissing sound, as from other stationary indirect-arc furnaces. There were recovered 58.6 pounds of ingot, and 3 pounds of metal from spillings and skimmings, or a total of 61.6 pounds. The net loss was 4.15 pounds or 6.45 per cent. Part of this loss was doubtless due to soakage into the new hearth.

HEAT L2.

Thirty-seven minutes after the arc was stopped on the previous heat, 55.4 pounds of ingot, containing about 25 per cent zinc, was charged and the arc started again. After the furnace had been heated 22 minutes without rocking, 6.4 pounds of zinc was added to the molten metal, in order to bring the composition up to that of 2:1 yellow brass, making a total charge of 61.8 pounds. It took 4 minutes to open the furnace, add the zinc, and lute the door. The arc was then run again for 5 minutes, with constant rocking of the furnace. The furnace was usually rocked at the rate of 5 or 6 complete swings a minute—a complete swing being from one extreme position of the furnace to the other extreme and back to the original position. Of course, the metal could not be allowed to run against the door, as it would either break through the luting and run out or else freeze in the joint and make opening of the door impossible. The metal covered, in its path, about three-quarters of the circumference of the furnace. During the whole run 12.5 kilowatt-hours was used. The metal was poured at 1,080° C. There was no indication of local overheating as in the first heat. There were recovered 59.7 pounds of ingot and 0.9 pound of shot, spillings, and skimmings, washed free from dirt and dross. Therefore the loss was 2.1 pounds or 3.5 per cent. As this was the first heat in which the furnace was rocked, some soakage into that part of the hearth not covered by the previous heat was to be expected.

HEAT L3.

The furnace had cooled 2½ hours after the preceding test. It was preheated 10 minutes, using 4.75 kilowatt-hours, then 60 pounds of 30 per cent zinc ingot was charged. After 13 minutes heating 3.6 pounds of zinc was added and the furnace was heated 8 minutes longer. In this run, and in all subsequent ones, rocking was begun before all the metal was melted, and continued all the time the arc was on. When the charge was added in two or more parts, the rocking was begun, at the rate of about six complete cycles per minute, as soon as the metal first charged was expected to be partly melted, and kept up till the rest of the charge was put in; then as soon as the next charge had partly melted down, rocking was again begun and kept up thereafter. Including the 4.75 kilowatt-hours used in preheating the already slightly warm furnace, the total power consumption in this heat was 19 kilowatt-hours. The metal was poured at 1,100° C.; 61 pounds of ingot and 0.7 pound of shot were recovered, showing a loss of 1.3 pounds or 2.05 per cent.

HEAT L4.

The heat was started with 60.5 pounds of 30 per cent zinc ingot, 26 minutes after the arc was stopped on the preceding heat. After 18 minutes 3.1 pounds of zinc, to make the metal correspond to 2:1 yellow brass, was added, with a pound of common salt as flux. After heating for 4 minutes longer, the metal was at 1,090° C., and was poured. Sixty-two pounds of ingot and 1 pound of shot were recovered, showing 0.95 per cent loss. The power consumption was 14.5 kilowatt-hours.

HEAT L5.

The furnace, started cold, was preheated 20 minutes, using 15 kilowatt-hours. Then 60.95 pounds of ingot was charged, and the furnace was heated 19 minutes, when 1.2 pounds of zinc and 1 pound of common salt were charged. Heating was continued 7 minutes, when 11 kilowatt-hours had been used, making a total of 26, including preheating. The metal was then at 1,105° C., and was poured. There was recovered 60.3 pounds of ingot and no shot, hence the loss was 1.85 pounds, or 2.90 per cent.

HEAT L6.

In 20 minutes after the previous run, the furnace was charged with 62 pounds of ingot and started again. After 17 minutes heating, 0.6 pound of zinc and some salt were added and the arc was run 6 minutes more; then the metal was at 1,095° C. and was poured. The total power consumption was 12.5 kilowatt-hours. In all, 61.8 pounds of ingot and 0.6 pound of shot were recovered. The total loss was 0.2 pound or 0.30 per cent.

HEAT L7.

After cooling 1½ hours, the furnace was preheated 5 minutes, with a power consumption of 4 kilowatt-hours; then 60.3 pounds of ingot was charged, with 2 pounds of glass as flux. After 12 minutes the furnace was opened for 2 minutes to observe the charge. Then it was run at a lower power input for 12 minutes more, when 1.1 pound of zinc was added. The temperature was found to be 1,100° C., and the metal was poured. The power consumption, including that used in preheating, was 18 kilowatt-hours. Sixty pounds of ingot was recovered, and no shot. The glass stuck in the furnace and probably held some metal. The apparent loss was 1.4 pounds or 2.25 per cent.

HEAT L8.

After standing 18 minutes the furnace was started with 61.7 pounds of ingot in, and was run 15 minutes. Then 0.9 pound of zinc and 2 pounds of glass were added. Low power was used for 8 minutes, when the metal was at 1,090° C. and was poured. This temperature is suitable for pouring 2:1 yellow brass, but was too low to melt the glass slag properly.

The power consumption in this heat was 14 kilowatt-hours, but in order to make the slag fluid enough to scrape out, 3 kilowatt-hours more was used.

The recovery was 60.75 pounds of ingot and 1.25 pounds of shot, and the apparent loss was 0.6 pound, or 0.75 per cent.

Excluding the first two heats, because of soakage into the new lining, the average loss of 2:1 yellow brass in these tests, based on the last six heats, is 1.6 per cent.

HEATS WITH MISCELLANEOUS SCRAP.

The next heats were on material loaned by the Hays Manufacturing Co., Erie, Pa., the charge being made up to correspond with one of its formulas. The ninth and tenth heats were intended to give metal like the Hays "yellow" brass, which contains about 25 per cent zinc. Those charges were made up from gates, fairly free from adhering sand; fairly clean scrap copper; dirty, oxidized shot recovered from ashes and spillings by concentration and called "kretz" by the Hays company, and of yellow-brass junk, which comprised old brass tubing, faucets, some being nickel-plated, old clock wheels, locks, etc. Pieces of wood, leather washers, and rubber packing, as well as much adhering grease and dirt, were found in this material. Its true metallic content was, of course, unascertainable.

HEAT L9.

The charge consisted of 10 pounds of "kretz," 6.6 pounds of yellow gates, 3.5 pounds of scrap copper, 46.7 pounds of yellow junk; total, 66.8 pounds (nominal, not true metallic weight).

After the cold furnace had been preheated 22 minutes, all the charge except about half the junk was put in, and in 8 minutes had melted enough so that the rest of the junk, with 1 pound of common salt and some charcoal, could be charged. The arc was then run 20 minutes, 14 kilowatt-hours being used, or 29 including preheating.

The metal was then at 1,060° C. and was poured. The melt was, however, a trifle cold and contained many chunks of porous, coke-like, slaggy dross from the dirt in the junk and kretz.

A recovery of 63.3 pounds of ingot and 0.3 pound of shot was obtained. The apparent loss was 3.2 pounds of material, or 4.80 per cent, but all of this material was not metal.

HEAT L10.

The charge used in this run was 10 pounds of "kretz," 6.6 pounds of yellow gates, 3.3 pounds of scrap copper, 46.7 pounds of yellow junk; total, 66.6 pounds. The furnace had stood about 22 minutes after the previous run. The current was started with all the charge in, except about half the junk. After 12 minutes the rest of the charge, with common salt and charcoal, was added. After 16 minutes' more heating the temperature was 1,060° C., which was not quite hot enough, so the heating was continued 4 minutes more, when the metal was at 1,090° C. and was poured. In this heat 17.75 kilowatt-hours was used. From the melt 63.9 pounds of ingot and 0.1 pound of shot were recovered, or 64 pounds in all; therefore the apparent loss was 2.6 pounds, or 3.80 per cent (not all metal).

HEAT L11.

After two hours, a heat designed to make red brass from a charge of Hays materials was started. The charge was 14.7 pounds of red gates, 25 pounds of scrap copper, 25 pounds of yellow chips (probably about 25 per cent zinc), 1.25 pounds of tin, 1.05 pounds of lead; total, 67 pounds. This mixture gives about 10 to 12 per cent zinc in the alloy.

The furnace was not preheated, but was slightly warm from the preceding test. The gates and most of the copper were put in and the arc run 22 minutes with a power consumption of 12.5 kilowatt-hours. Then the rest of the copper and the chips, with 2.5 pounds of glass and some charcoal, were added and the arc was run 15 minutes longer, 7.5 kilowatt-hours being used. The addition of the chips had frozen the charge and although they were melted at 1,090° C. all the copper and the gates had not melted, some being still solid in the bottom. After 2.5 kilowatt-hours had been put in for 7 minutes, the whole charge was melted and was at 1,045° C. Then 6.25 kilowatt-hours was put in in 9 minutes, when the temperature was 1,250° C. and the metal was poured. The glass was nicely fluid.

The whole heat took 28.75 kilowatt-hours. From this heat 66.1 pounds of ingot and 0.5 pound of shot were recovered, showing a loss based on the total charge, of 0.4 pound, or 0.60 per cent.

HEAT L12.

After 25 minutes, a run with a charge similar to that used in heat L11 was started. The charge consisted of 25 pounds of scrap copper, 25 pounds of yellow chips, 14.75 pounds of red gates, 1.15 pounds of lead, 1.4 pounds of tin; total, 67.3 pounds.

After 23 minutes, in which 11.5 kilowatt-hours was used, the balance of the charge, with glass and charcoal, was put in. After 18 minutes' further heating, in which 11.5 kilowatt-hours more was used, the temperature was found to be 1,305° C., which was too hot. Then 5.3 pounds of red gates was added, reducing the temperature to about 1,250° C., when the metal was poured. Thus 23 kilowatt-hours was used for 72.6 pounds of metal.

From this, 70.6 pounds of ingot and 0.3 pound of shot were recovered, giving an apparent loss of 1.6 pounds, or 2.20 per cent. The one-half inch thick asbestos cement lining was seen to have cracked off in a few places, being too thick to be elastic enough and too thin to hold up after cracking. Hence this asbestos lining was chipped out, and as a result 1.8 pounds of metal was recovered from behind the cracks. If this be credited to the last heat, the result shows an apparent gain. The bulk of this metal, however, should be credited to the last two heats, as before these the lining showed no visible cracks. The results of these two heats taken together then show a net loss of 0.2 pound on 139.6 pounds of metal, or 0.15 per cent.

Then a thin layer, not more than one-fourth inch, of a wash consisting of a mixture of fire clay and graphite, used for crucibles, was put in, and the furnace was dried out. After the furnace had cooled, a few tiny cracks appeared; these were patched.

HEAT L13.

In order to saturate the hearth, a heat was made of about 50 pounds of miscellaneous waste metal and slag. The charge was so dirty that a recovery of not more than 40 pounds was expected. The furnace, which had some moisture in it from the final patching, was dried and preheated for 25 minutes, using 13.5 kilowatt-hours, and then the whole 50 pounds of junk was charged. After 38 minutes' heating, using 14.5 kilowatt-hours, the contents were at 1,090° C. and were poured into ingot. Including the preheating, 28 kilowatt-hours was used, in all, and 43.6 pounds of ingot was recovered.

HEAT L14.

After 24 minutes another heat of 63 pounds of the ingot obtained in runs L9 and L10 was begun. All the metal, with salt and charcoal, was put in at the start.

After 23 minutes, in which 15.5 kilowatt-hours was used, the metal was at 1,170° C. As this was too hot for material with a 25 per cen zinc content, 3.5 pounds of yellow gates was added, bringing the temperature down to about 1,150° C. From this charge 66.1 pounds of ingot and 0.2 pound of shot were recovered, showing a loss of 0.2 pound, or 0.30 per cent.

HEAT L15.

The furnace, after standing 1 hour 10 minutes, was preheated for 10 minutes, using 5 kilowatt-hours, then all of a 64.2-pound charge of ingot from heats L9 and L10, with salt and charcoal, was put in. In 23 minutes, with a power consumption of 13.25 kilowatt-hours, the metal was at 1,190° C., or a little too hot, so 3.6 pounds of yellow gates was added, bringing the temperature down to about 1,150° C. A total of 18.25 kilowatt-hours was used for melting 67.8 pounds of metal. From this 67 pounds ingot and 0.3 pound of shot were recovered; thus the loss was 0.5 pound or 0.75 per cent. The average loss in heats L14 and L15 was about 0.5 per cent, whereas the average in L9 and L10, from dirty junk, was about 4.4 per cent. This indicates that the bulk of the loss in heats L9 and L10 was dirt, not metal.

HEAT L16.

After 16 minutes a heat of Hays yellow chips, containing about 25 per cent zinc, was begun. The whole charge of 50 pounds (no allowance being made for oil or dirt, some of both being present) with salt and charcoal was put in. In 20 minutes, using 11.75 kilowatt-hours, the metal was at 1,230° C., or much too hot, and was "jumping" noticeably, so 4.9 pounds of yellow gates was added. This reduced the temperature to about 1,150° C. From the 54.9-pound charge 53.75 pounds of ingot and 0.15 pound of shot were recovered, showing a loss of 1 pound, or 2 per cent, which is well below the results obtained in practice with fuel-fired furnaces.

HEAT L17.

After 17 minutes, a charge of 50 pounds of Hays red chips, which are about 10 per cent zinc, was put in with charcoal and heated in 18 minutes, using 12 kilowatt-hours, to 1,240° C., which was too hot. Then 4.15 pounds red gates was added, reducing the temperature to about 1,200° C. No allowance was made for oil or dirt, and a little oil was present. From the 54.15 pounds charged, 52.2 pounds of ingot and 0.4 pound of shot were recovered, hence the loss was 0.55 pound or 1 per cent.

HEAT L18.

In heat L18, power consumption and metal losses were secondary, as the heat was run for the purpose of testing pyrometers for brass in molten metal at high temperatures. This meant holding the metal in the furnace a long time and having the door open a great deal.

The furnace was first preheated 8 minutes, using 5 kilowatt-hours, then some very bulky red brass gates were charged, the power being off 12 minutes. Then the arc was run 25 minutes, using 8.5 kilowatt-hours, and more gates were charged. After being off 5 minutes the arc was run 16 minutes, using 11 kilowatt-hours. After another 5-minute period in which the rest of the 67-pound charge of gates was put in, the arc was run 7 minutes, using 5.5 kilowatt-hours, when the temperature was 1,000° C. After being off for 8 minutes, the arc was run 10 minutes, using 6 kilowatt-hours, when the temperature was 1,200° C. In the whole heat, including preheating, 35 kilowatt-hours was used, starting with a cold furnace. The pyrometer tests were then started, the door being open most of the time, while the power was off. After 18 minutes 5 kilowatt-hours more was used in 8 minutes. The temperature was then 1,215° C. After 13 minutes 4 kilowatt-hours was put in in 5 minutes, but so much heat had been lost in the 13 minutes the power was off and the door open that the temperature was only 1,160° C.

The power was only off 5 minutes after this, and 4 kilowatt-hours in 8 minutes gave a temperature of 1,280° C. The furnace was then left open till the temperature had fallen to about 1,200° C., when the metal was poured.

The door was open a good deal while the metal was at 1,160° to 1,280° C. Yet the metal loss was only 0.5 pound or 0.75 per cent, as 66.1 pounds of ingot and 0.4 pound of shot were recovered.

HEAT L19.

In heats L19 to L22, inclusive, the charge was 70 pounds of scrap yellow brass, 10 pounds of yellow gates, 5 pounds of scrap copper, and 15 pounds of "kretz." The aim was to make a yellow brass containing about 25 per cent zinc. In addition to the metal, 2 pounds of salt and a double handful of charcoal were used on each heat.

Heat L19 began at 8 a. m. in a cold furnace with all the charge in the furnace at the start, save about 30 pounds of scrap. After 30 minutes, when 19 kilowatt-hours had been used, rocking was started. At 8.34, when 21.6 kilowatt-hours had been used, the rest of the charge was put in and the salt added. The arc was off 5 minutes, till 8.39. At 8.45 rocking was again begun and at 8.58, when 32 kilowatt-hours had been used, the temperature was 1,115° C. This was a little cold, so after 3 minutes had been spent in opening the door, taking the temperature, and closing and luting the door, the arc was started again and run till 9.08, when 35 kilowatt-hours had been used, and the metal was at 1,145° C. and was poured.

From the 100-pound charge 93.5 pounds of ingot and 2 pounds of shot, 95.5 pounds in all, were recovered, giving an apparent loss of 4.5 per cent.

HEAT L20.

At 9.23, with all the charge in except about 40 pounds of scrap, the arc was started. At 9.51, when 12.7 kilowatt-hours had been used, the rest of the charge and the salt were put in. After 6 minutes the arc was started again and run till 10.21, when 24.2 kilowatt-hours had been used and the metal was at 1,145° C. From this run 95.15 pounds of ingot and 0.7 pound of shot, or 95.85 pounds in all, were recovered, giving an apparent loss of 4.15 per cent.

HEAT L21.

Heat L21 was started at 10.37 a. m. with all the metal, except 40 pounds of scrap, in the furnace. At 10.59, when 10 kilowatt-hours had been used, the rest of the metal and the salt were charged and the arc was started after being off 5 minutes. At 10.27, when 21 kilowatt-hours had been used, the temperature was over 1,200° C. and 5.3 pounds of gates was added to bring the temperature down to about 1,175° C. before pouring. There were recovered 100.9 pounds of ingot and 0.7 pound of shot, or 101.6 pounds in all, giving an apparent loss of 3.55 per cent.

HEAT L22.

At 11.40 a. m. all the charge except 40 pounds of scrap was put in and left without running the arc till 12.37, when the arc was started. At 1 p. m., when 7 kilowatt-hours had been used, the rest of the charge and the salt were put in and at 1.04 the arc started again and run till 1.27, when 18 kilowatt-hours had been used. The temperature was found to be 1,050° C. After a 4-minute stop the arc was run till 1.38, when 21 kilowatt-hours had been used, and the metal was at 1,135° C. As a result, 95.15 pounds of ingot and 1.1 pound of shot, or 96.25 pounds in all, were poured, giving an apparent loss of 3.75 per cent.

HEAT L23.

The next heat was on the dirty "kretz" alone. Fifty pounds of this material, with some charcoal, was put in at the start, at 2.01 p. m., and was heated 37 minutes, when 15 kilowatt-hours had been used and the temperature was 1,210° C.

From this run 40.2 pounds of ingot and 1.1 pounds of shot, or 41.3 pounds in all, were recovered, showing a loss of 17.4 per cent. The amount of slag was large.

It is evident that not more than 85 per cent of the "kretz" is metallic material. On this basis 15 pounds of "kretz" used in a 100-pound charge of yellow brass would contain 2.25 pounds of nonmetallic material. H. H. Clemens, of the Hays Manufacturing Co., stated that there was about one-half pound of dirt on the 70 pounds of yellow brass scrap used for each 100-pound charge. The nonmetallic content from these two sources is then at least 2.75 per cent.

The losses on heats L9, L10, and L19 to L22, inclusive, may be corrected as follows:

Losses in heats L9, L10, and L19 to L22, corrected for nonmetallic material.

Heat.	Apparent loss (based on weight of charge).	Real loss (based on metal content of charge).
	Per cent.	*Per cent.*
9	4.80	2.05
10	3.90	1.15
19	4.50	1.75
20	4.15	1.40
21	3.55	.80
22	3.75	1.00
Average	4.10	1.35

HEAT L24.

At 8.30 a. m. a heat aimed to produce 2:1 yellow brass was begun with a charge of 37.8 pounds of 2:1 yellow-brass ingot and 43.2 pounds of ingot copper in the cold furnace. At 9:11 a. m., after 28 kilowatt-hours had been used, 22.05 pounds of zinc was added. The arc was started again at 9.16 and run till 9.24, using in all 30.5 kilowatt-hours, when the temperature was 1,075° C. In this run 101 pounds of ingot and 1.3 pounds of shot, or 102.3 pounds in all, were recovered, thus the loss was 0.75 pound, or slightly less than 0.75 per cent.

HEAT L25.

Heat L25 was on a red-brass composition containing about 10 per cent zinc. The original charge was 37.5 pounds of scrap copper, 21.5 pounds of red gates, 37.5 pounds of yellow (25 per cent zinc) chips, 1.75 pounds of lead, and 1.85 pounds of tin; total weight, 100.10 pounds.

Most of the copper and gates were put in at the start at 9.42 a. m., and at 10.05 a. m. after 12 kilowatt-hours had been used, the rest of the charge, with charcoal and no flux, was put in. After 6 minutes the arc was started again and run till 10.32 a. m., when 25 kilowatt-hours had been used. The temperature was 1,230° C., which was too hot, so 6 pounds of red gates was added, reducing it to about 1,200° C.

TABLE I.—*Results of 28 heats in laboratory electric rocking brass furnace.*

Heat (Lab. No.).	Composition aimed at in melt.	Kind of material charged.[a]	Weight of material charged.	Flux.	Condition of furnace at start.	Ingot poured.	Shot poured.	Total metal recovery.	Net loss of metal.	Temperature of pouring.	Total power consumption.	Power consumption per hundred pounds of metal.
			Pounds.			*Pounds.*	*Pounds.*	*Pounds.*	*Per ct.*	° *C.*	*Kw. hrs.*	*Kw. hrs.*
L1	Yellow brass (2:1)	"2:1" yellow ingot	65.75	None	Cold [b]	58.6	3.0	61.6	6.45	1,075	33.5	51
L2	do	"25 per cent zinc" ingot (55.4 pounds) and metallic zinc (6.4 pounds).	61.8	do	Hot [c]	59.7	.9	60.6	3.5	1,080	12.5	20.75
L3	do	"30 per cent zinc" ingot (60) and zinc (3.6).	63.6	do	Nearly cold	61.0	.7	61.7	2.05	1,100	19	30
L4	do	"30 per cent zinc" ingot (60.5) and metallic zinc (3.1).	63.6	Common salt	Hot	62.0	1.0	63.0	.95	1,090	14.5	23
L5	do	Ingot (60.95) and zinc (1.2)	62.15	do	Cold	60.3	None.	60.3	2.90	1,105	26	45
L6	do	Ingot (62) and zinc (0.6)	62.6	do	Hot	61.8	.6	62.4	.30	1,095	12.5	20
L7	do	Ingot (60.3) and zinc (1.1)	61.4	Glass	Warm	60.0	None.	60.0	2.25	1,100	18	29.5
L8	do	Ingot (61.7) and zinc (0.9)	62.6	do	Hot	60.75	1.25	62.0	.95	1,090	14	22.5
L9	Yellow brass (25± per cent zinc).	Yellow "junk (46.7)," "kretz" (10), yellow gates (6.6), and scrap copper (3.5).	66.8	Salt	Cold	63.3	.3	63.6	[d] 4.80 [f] 2.05	[e] 1,060	29	42.5
L10	do	Yellow "junk" (46.7), "kretz" (10), yellow gates (6.6), and scrap copper (3.3).	66.6	do	Hot	63.9	.01	64.0	[d] 3.90 [f] 1.15	1,090	17.75	26.5
L11	do	Red gates (14.7), yellow chips (25), scrap copper (25), tin (1.25), and lead (1.05).	67.0	Glass	Slightly warm	66.1	.5	66.6	.60	1,250	28.75	43
L12	do	Red gates (20.05), yellow chips (25), scrap copper (25), tin (1.4), and lead (1.15).	72.6	do	Hot	70.7	.3 1.8	71.0 from lining	[b] 2.20	1,250	23	31.5
L13	Indeterminate	Dirty waste	139.6 [g] 50.0	Salt	Cold	136.8 (43.6)	2.6	139.4	.20	1,090	28	63.5
L14	Yellow brass (25± per cent zinc).	"25 per cent" ingot from heats L9 and L10 (63) and yellow gates (3.5).	66.5	do	Hot	66.6	.2	66.3	.30	1,150	15.5	24.5
L15	do	"25 per cent" ingot from heats L9 and L10 (64.2) and yellow gates (3.6).	67.8	do	Warm	67.0	.3	67.3	.75	1,150	18.5	28.5

L16	....do	Yellow "25 per cent" chips (50) and yellow gates (4.9).	54.9	....do	Hot	53.75	.15	53.9	2.0	1,150	11.75	26.5
L17	Red brass (10± per cent zinc).	Red chips (50) and red gates (4.15)	54.15	None	....do	53.2	.4	53.6	1.0	1,200	12	24
L18	....do	Red gates	67.0	....do	Cold	66.1	.4	[h] 66.5	.75	1,200	35	52
L19	Yellow brass (25± per cent zinc).	Yellow "junk" (70), yellow gates (10), "kretz" (15), and scrap copper (5).	100.0	Common salt	....do	93.5	2.0	95.5	[d] 4.5 [f] 1.75	1,145	35	35
L20	....do	Same as in L19	100.0	....do	Hot	91.15	.7	95.85	[d] 4.15 [f] 1.40	1,145	24.2	24.2
L21	....do	Same as in L19, plus (5.3) of gates	105.3	....do	....do	100.9	.7	101.6	[d] 3.55 [f] .80	1,175	21	20
L22	....do	Same as in L19	100.0	....do	....do	95.15	1.1	96.25	[d] 3.75 [f] 1.00	1,135	21	[i] 21
L23	Indeterminate	"Kretz"	50.0	None	....do	40.2	1.1	41.3	[d] 17.4	1,210	15	30
L24	Yellow brass (2:1)	2:1 brass ingot (37.8) and copper ingot (43.2).	103.5	....do	Cold	101.0	1.3	102.3	.75	1,075	30.5	30
L25	Red brass (10± per cent zinc).	Red gates (21.5), yellow chips (37.5), scrap copper (37.5), lead (1.75), and tin (1.85).	106.15	....do	Hot	104.95	.70	105.65	.50	1,200	25	23.6
L26	....do	Red gates (21.5), yellow chips (37.5), scrap copper (37.5), lead (2.5), and tin (2).	107.3	....do	....do	106.0	.7	106.7	.55	1,200	21.2	20
L27	Yellow brass (25± per cent zinc).	Yellow chips	100.0	Common salt	....do	98.2	.7	98.9	1.1	1,100	21	[i] 21
L28	Red brass (10± per cent zinc).	Red chips	49.85	None	....do	48.7	.65	49.35	1.00	1,200	12	24

[a] Figures in parentheses refer to weight of material in pounds.

[b] New hearth; furnace not rocked.

[c] Furnace rocked only after speltering; bath in contact with new lining.

[d] Apparent loss, based on weight of material charged.

[e] Temperature was too cold for good pouring.

[f] Actual loss, based on estimated weight of metallic material in charge.

[g] Includes dirt.

[h] Held in furnace one hour before pouring.

[i] Furnace was charged while hot from previous run, then stood about one hour before current was turned on

The total weight of the metallic materials charged was 106.1 pounds. From this 104.95 pounds of ingot and 0.70 pound of shot, or 105.65 pounds in all, were recovered, showing a loss of 0.45 pound or slightly less than 0.45 per cent.

HEAT L26.

Heat L26 was on a red-brass composition similar to that used in heat L25. The original charge was 37.5 pounds of scrap copper, 21.5 pounds of red gates, 37.5 pounds of yellow chips, 2.0 pounds of tin, and 2.5 pounds of lead, total 101.0 pounds. Most of the scrap and gates were put in at the start, at 10.40 a. m. At 11.08 a. m., when 8 kilowatt-hours had been used, the rest of the charge, with some charcoal, was put in. After 6 minutes, the arc was started again and run till 11.35 a. m. when 21.2 kilowatt-hours had been used. The temperature was 1,240° C., so 6.3 pounds of red gates was added, lowering it to about 1,200° C.

The total charge was 107.3 pounds; 106.0 pounds of ingot and 0.7 pound of shot, or 106.7 pounds in all, were poured, showing a loss of 0.6 pound or about 0.55 per cent.

HEAT L.27

At 11.45 a. m. about 60 pounds of a heat of 100 pounds of yellow chips (25 per cent zinc) was put into the furnace, and left till 12.32 p. m., when the arc was started. At 12.45, when 8.3 kilowatt-hours had been used, the rest of the charge, with some common salt and charcoal, was added. After being off 6 minutes, the arc was run for 19 minutes, when 18 kilowatt-hours had been used. The temperature was only 1,040° C. After a 4-minute interval the arc was run again for 6 minutes, till 1.20 p. m., when 21 kilowatt-hours had been used and the temperature was 1,100° C.

There were poured 98.2 pounds of ingot and 0.7 pounds of shot, or 98.9 pounds in all were recovered, with a loss of 1.1 pounds, or 1.1 per cent.

HEAT L28.

Heat L28, on 49.85 pounds of red brass chips with a zinc content of 10 per cent, was started at 1.35 p. m. with all the charge, including charcoal, in the furnace. The arc was run until 2.01 p. m., when 12 kilowatt-hours had been used and the temperature was 1,200° C.

In this heat 48.70 pounds of ingot and 0.65 pound of shot, 49.35 pounds in all, were recovered, indicating a loss of 0.5 pound or about 1 per cent.

SUMMARY OF RESULTS OF THE 28 HEATS.

The results of the 28 heats are summarized in Table 1.

The data for metal losses, the first two heats being omitted because the furnace was not properly rocked, are as follows:

TABLE 2.—*Summary of data on metal losses in 24 heats.*

2:1 YELLOW BRASS.

Heat No.	Material used.	Pouring temperature, °C.	Apparent loss.	Net loss.
			Per cent.	*Per cent.*
L3	Yellow brass ingot and a little zinc	1,100		2.05
L4	do	1,090		.95
L5	do	1,105		2.90
L6	do	1,095		.30
L7	do	1,100		2.25
L8	do	1,090		.95
L24	Yellow brass ingot, copper, much zinc	1,075		.75
Average				1.5

YELLOW BRASS (25± PER CENT ZINC).

Heat No.	Material used.	Pouring temperature, °C.	Apparent loss.	Net loss.
L9	Scrap, gates, "kretz," lead, and tin	1,060	4.80	2.05
L10	do	1,090	3.90	1.15
L19	do	1,145	4.50	1.75
L20	do	1,145	4.15	1.40
L21	do	1,175	3.55	.80
L22	do	1,135	3.75	1.00
Average			4.10	1.35
L14	Ingot from heats L9 and L10	1,150		.30
L15	do	1,150		.75
Average				.50
L16	Chips	1,150		2.00
L27	do	1,100		1.10
Average				1.60

RED BRASS (10 PER CENT ZINC.)

Heat No.	Material used.	Pouring temperature, °C.	Apparent loss.	Net loss.
L11	Scrap copper, 25 per cent zinc yellow chips, gates, lead, and tin	1,250		0.60
L12	do	1,250		.20
L25	do	1,200		.50
L26	do	1,200		.55
Average				.50
L18	Gates	1,200		[a].75
L17	Chips	1,200		1.00
L18	do	1,200		1.00
Average				1.00

[a] Melt held in furnace 1 hour before pouring.

TESTS ON CONCENTRATES FROM BRASS-FURNACE ASHES.

The concentrates from brass-furnace ashes are usually sent to a smelter where the copper only is recovered. If the other metals could be recovered also, the increased recovery might pay for electric melting.

Some concentrate of about 20-mesh fineness was loaned the Bureau of Mines by W. S. Rowland, of the Connecticut Metal & Chemical Co., for testing in the rocking furnace. The composition of this material was, according to an analysis supplied by Mr. Rowland, as follows:

Composition of brass-furnace concentrate tested.

	Per cent.
Copper	71.0
Zinc	14.3
Iron	[a] 2.2
Lead	None.
Tin	None.
Insoluble	7.2

HEAT L29, L30, AND L33.

All the charge, 75 pounds of concentrate, with 0.4 pound of 4-mesh charcoal, was put into the cold furnace at the start, heated 68 minutes, using 38.25 kilowatt-hours, and was poured at 1,240° C.

In all, 43.6 pounds of ingot and 7.75 pounds of slag were poured. The slag poured was fairly fluid, but much slag stuck in the furnace and could not be scraped out.

In run L30, 75 pounds of concentrate, 0.5 pound of 10-mesh charcoal, and 1 pound lime (partly air-slaked), were charged into the hot furnace. After 25 minutes, when 13.5 kilowatt-hours had been used, the temperature was 1,100° C, and 39.3 pounds of ingot and 8 pounds of slag were poured. Heating was then continued 15 minutes, using 9.5 kilowatt-hours, when the metal was at 1,240° C.; 15.1 pounds of ingot and 9 pounds of slag were poured. Then heating was continued 8 minutes, using 5.5 kilowatt-hours, and 2.7 pounds of ingot and 2 pounds of slag were poured. The total power consumption was 28.5 kilowatt-hours. As some of the slag still stuck in the furnace, the latter was allowed to cool, and the slag was chiseled out. One chunk of caked material, weighing 12.2 pounds, evidently from heat L29, was found in the bottom, covered with slag. Evidently a viscous slag had formed over this mass and prevented the tiny buttons from coalescing. In cleaning the furnace 13.5 pounds of slag, buttons, and pieces of lining were taken out.

The furnace was then clean and practically free from slag or shot. The slag from heats L29 and L30 and the mixed slag, lining, etc., that had been chiseled out was crushed in a jaw crusher. This crushed material was freed from the larger pieces of slag by panning in a stream of water.

After the next two heats, L31 and L32, were over, this material was melted. This "concentrate" and the matted pieces plus the spillings from heats L29 and L30 weighed 24.5 pounds. This material, with 4 pounds of salt, a handful of charcoal, and 1 pound of lime, was charged into the hot furnace.

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[a] Iron content is high, as the material has not been properly treated with magnetic separator.

The heat (No. L33) continued 17 minutes, and used 10 kilowatt-hours. The temperature was not taken, but was about 1,200° C. When the furnace was poured, 14.8 pounds of ingot and spillings and 6.5 pounds of slag were obtained, and 0.5 pound of shot was recovered from the slag. The slag was not homogeneous, although the salt floated off the stony particles of thick slag and lining in the "concentrate" fairly well.

The total concentrate charged for these three heats was 150 pounds. The recovery of ingot was lot 1, 43.6 pounds; lot 2, 39.3 pounds; lot 3, 15.1 pounds; lot 4, 2.7 pounds; lot 5, 14.8 pounds; and of shot, 0.5 pound, making a total of 116 pounds, or 77.4 per cent of the concentrate charged.

The 150 pounds of concentrate contained 106.5 pounds of copper and 21.5 pounds of zinc. Thus in these heats all the copper and about half the zinc were recovered. The slag was too viscous in all three of the runs. The slag in heat L30 was less viscous than in heat L29, but still too thick. When the furnace had been patched after being chiseled out, a heat was made with an increased proportion of lime.

HEATS L31 AND L32.

In heat L31, 63.15 pounds of concentrate, 1.5 pounds unslaked lime (CaO) and 0.3 pound 10-mesh charcoal were charged into the cold furnace, and the arc run 46 minutes, using 32.5 kilowatt-hours. The temperature was 1260° C. The metal and the slag were poured together into ingot molds, and when the mass had frozen, the slag was knocked off. From this melt 49.6 pounds of ingot and 12 pounds of slag were obtained. A little slag clung to the lining, but the slag was nicely fluid and the metal separated well, only 0.1 pound shot and spillings being obtained. Thus the total recovery was 61.7 pounds.

In the next heat (L32) 64 pounds of concentrate, 1.5 pounds of lime, 0.5 pound of fluorspar, and 0.4 pound of charcoal were charged into the hot furnace. After 31 minutes, when 20 kilowatt-hours had been used, the temperature was 1,235° C. The slag was nicely fluid, but not more so than without the fluorspar. The slag and the metal were poured together into the molds. In all, 49.3 pounds of ingot and 14 pounds of slag were poured, and 0.1 pound of shot and spillings was recovered, making a total recovery of 63.4 pounds.

In these two heats 127.15 pounds of concentrates was charged, corresponding to 90.3 pounds of copper and 18.2 pounds of zinc. The total recovery was 99.1 pounds or 78 per cent of the charge, or roughly, all the copper and half of the zinc were recovered. Hence a ton of this concentrate should give 1,560 pounds of metal containing 1,420 pounds of copper and 140 pounds of zinc.

Analyses of the ingot obtained in this melt showed that the recovery of copper from the original concentrate was more than 99 per cent. The exact figures were lost in a fire that destroyed the Bureau of Mines office in Morse Hall, Cornell University, after these tests were completed.

Lyon and Keeney[a] state that 600 calories per kg. of slag and 204 calories per kg. of metal were required for melting and superheating copper concentrates in an electric furnace. Hence it was thought that the presence of the slag would greatly increase the power consumption over that of melting metal free from slag.

However, in heat L32, a second heat with the furnace warm, 20 kilowatt-hours was used in heating 66.4 pounds of concentrate, or 30 kilowatt-hours per 100 pounds, to 1,235° C., in heat L10, also a second heat, 72.6 pounds of metal was heated to 1,250° C. with a power consumption of 23 kilowatt-hours, or 31.5 kilowatt-hours per hundredweight.

Hence it seems probable that in melting such material the power consumption would not be much larger than with metal.

POWER-CONSUMPTION TESTS.

The tests recorded in the preceding paragraphs were made on charges not so large as the furnace would take, so a series of heats were made with 128-pound charges, to get some idea of the power consumption.

In the next five tests the charge consisted of about 94 pounds of red and yellow ingot and 33 pounds of scrap copper, being designed to give a red brass containing 81.5 per cent copper, 8.5 per cent zinc, 6 per cent lead, and 4 per cent tin. In each test the whole charge was put into the furnace at the start, no further opening of the furnace being necessary.

The furnace was cold at the start. The power was off during pouring. The total time required for the five heats, including charging and pouring, was five hours. The average time between stopping the arc on one heat and starting it on the next was 18 minutes. This period was used in taking the temperature, pouring, charging, and sealing the door with fire clay.

In all of these heats rocking was begun when about half the power consumption for any given heat had been used. The results of the run follow:

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[a] Lyon, D. A. and Keeney, R. M., The smelting of copper ores in the electric furnace: Bull. 81, Bureau of Mines, 1915, p. 36.

Results of heats to determine power consumption.

Heat No.	Weight of charge, pounds.	Time arc was on, minutes.	Pouring temperature, °C.	Average power input; kw.-hours.	Number of kw.-hours used.	Power consumption, kw.-hours per 100 pounds of metallic material charged.
34	127.3	57	1,140	40	39	30.5
35	127.75	50	1,180	36.5	30.5	25
36	128.5	50	1,220	32	26.5	20.5
37	126.5	37	1,220	36.5	22.5	17.75
38	129.5	36	1,220	32	19	14.75
Total or average	639.55	46	1,200	36	136.5	21.5

As regards metal losses, 630.9 pounds of ingot was poured, giving a gross loss of 8.65 pounds, or 1.35 per cent, and 7.45 pounds of metal from spillings, skimmings, and buttons left in the furnace was recovered. Thus the total recovery was 638.35 pounds, giving a net metal loss of 1.2 pounds, or 0.19 per cent.

During these five heats the weight of electrodes consumed was 1 pound.

The power consumption, which was at the rate of 430 kilowatt-hours per ton on a five-hour run, starting with the furnace cold, and at the rate of 295 kilowatt-hours per ton when the furnace is hot, on metal heated to 1,200° C., is surprisingly low for so small a furnace.

TESTS ON MANGANESE-BRONZE BORINGS.

The next test was on manganese-bronze borings, the main object being the determination of the metal losses. Through the kindness of Mr. V. Skillman, of the Lumen Bearing Co., about 350 pounds of borings was obtained from that company. This manganese bronze was originally made up to have a composition as follows: Copper, 58 per cent; zinc, 40.5 per cent; tin, 0.3 per cent; aluminum, 0.4 per cent; iron, 1.5 per cent; and a trace of manganese.

This lot of borings was very oily and contained many iron or steel turnings, as well as a little paper and sweepings. From 350.1 pounds, 0.45 pound of large iron borings, nuts, etc., was picked out by hand, leaving 349.65 pounds.

The oil content, determined by extraction with ether, was found to be 1.4 per cent, corresponding to 4.9 pounds.

There was probably a small amount of 2:1 yellow brass borings mixed with the manganese bronze, but not enough to alter materially the behavior of the borings as to metal loss.

HEAT L39.

The first heat (heat L39) of the series was started with 71.75 pounds of borings in the furnace. After 10 minutes, when 7.75 kilowatt-hours had been used. rocking was started, and after six minutes more—power input 3.75 kilowatt-hours—the rest of the charge, 48.25 pounds of borings, with 1.5 pounds of common salt and a little charcoal, was put in. The arc was off for nine minutes while the charge was being added and the door luted. Five minutes after the current was turned on, rocking was again begun and was continued for 24 minutes, when the door blew loose, zinc vapor shooting out all around it with a loud hissing sound. This indicated either too high a temperature of the bath, or local overheating. The temperature of the bath was found to be 1,050° C., which was too high, and the melt was "jumping" strongly. The metal was then poured.

No fluid slag was formed, although sodium chloride had been added for flux, but there was a fine, powdery dross, which was black, and contained much soot that could be floated off with water, tiny globules of manganese bronze, and much iron borings. A good deal of this dross stuck to the furnace walls, the melted sodium chloride evidently acting as a binder. The furnace was thoroughly scraped, but not much of the adhering dross could be removed. It seems possible that the soot formed from the decomposition of the oil helped to envelope the tiny globules of metal and to prevent them from coalescing.

From this melt 105.35 pounds of ingot and 1 pound of spillings were obtained, or 106.35 pounds of good metal. There was 0.2 pound of manganese-bronze shot and iron borings coarser than 14 mesh in the dross skimmed off, and 1.9 pounds of fine dross under 14-mesh.

The total time from the starting of the arc, exclusive of that for charging the cold furnace, was 54 minutes, during which the arc was on 45 minutes. The total power consumption was 32 kilowatt-hours in all, or 26.6 kilowatt-hours per 100 pounds of metallic material charged. The average power input was 41 kilowatts.

HEAT L40.

The arc was off 22 minutes between heats, this time being used in taking the temperature, pouring the melt, scraping the furnace, charging 71.55 pounds of borings, and luting the door. After 3.5 kilowatt-hours had been used rocking was started; then, after the arc had been on 15 minutes and 10 kilowatt-hours had been used, 48.55 pounds borings, 1.5 pounds of salt, and some charcoal were added. The arc was off 6 minutes for charging. The door was not luted tight at this time. After 3 minutes, when the oil had ceased to smoke and a small zinc flame came out instead of the smoky oil flame, the door was tightly luted and rocking was started again. The arc was run 24 minutes after the second part of the charge was in, 14.5 kilowatt-hours being used in this period.

The door did not blow loose, but when it was opened there was a marked outrush of zinc vapor, although not so violent as in heat L39. The temperature was 1,040° C.

The "jump" was strong, although not so strong as in the preceding test. Again there was no fluid slag, only powdery dross. The furnace was again carefully scraped.

In this run 109.2 pounds of ingot and 2.5 pounds of spillings, or 111.7 pounds of good metal, were obtained. The dross gave 1.1 pounds of manganese-bronze buttons and iron borings coarser than 14 mesh and 3.3 pounds of dross under 14 mesh. The period from the time of starting the arc to the final stopping of it was 45 minutes, of which the arc was on 39 minutes. The power consumption was 24.5 kilowatt-hours in all, or 20.2 kilowatt-hours per 100 pounds of metallic material charged. The power input averaged 38 kilowatts.

This heat being the last for which a charge of borings was on hand, all possible precautions were taken to prevent metal losses.

HEAT L41.

The power input was reduced, and the furnace door was not luted tight until after the smoky flame of the burning oil had ceased.

More salt was used to give a fluid slag and thus promote coalescence of the metal globules, and some of the salt was added with each charging of borings instead of after all the borings were in.

A lower pouring temperature was used, as in the commercial melting of manganese-bronze borings these would form only a small proportion of the charge if used without ingoting, and when all borings are run down to ingot, there is no reason for heating any hotter than enough to pour well.

However, the greatest alteration in procedure was the use of a smaller charge (about 110 pounds instead of 120, as before), and charging less material at one time. In heats L39 and L40, both at the start and at the second charging, borings were piled up to within about 2 inches of the arc. This condition would tend to cause local overheating before the charge had melted down enough to permit it being rocked without the electrodes becoming short-circuited from the mass of borings falling on them. In heat L27, on 100 pounds of yellow chips with 20 per cent zinc content, which gave only 1.1 per cent loss, 60 pounds was charged at the start and 40 pounds later.

In heat L41 the arc was started 19 minutes after it had been stopped on the preceding heat. Only 55 pounds was charged at the start, leaving 3 or 4 inches free space about the arc. Also 1.5 pounds of common salt and some charcoal were put in. After 3 kilowatt-hours had been used the door was luted tight, and when 5 kilowatt-hours had been used rocking was begun. In 21 minutes 8.5 kilowatt-hours had been used, then the arc was turned off for 6 minutes and about 30 pounds of borings and 1 pound of salt were charged. As soon as the oil had burned off the door was luted and rocking begun. After running 8 minutes with a power input of 4 kilowatt-hours, the arc was again shut off 5 minutes and the rest of the borings, about 25 pounds, with 1.5 pounds of sodium chloride, was charged. Luting and rocking were done as before. After 8 minutes, in which 5 kilowatt-hours was used, the temperature was 890° C. The arc was off 3 minutes for opening the furnace, taking the temperature, and reluting the door. It was then run 4 minutes—power input, 1.75 kilowatt-hours—and the temperature was 920° C. The metal did not "jump" when the pyrometer tube was thrust in, and poured well at this temperature. There was no outrush of zinc vapor when the furnace was opened, although there was some "zinc flare" from the stream of metal while pouring. The metal was covered with a fluid slag that skimmed well. The period from the moment the arc was first started until it was shut off at the end of the melt was 55 minutes. During this time the arc was on 41 minutes. The total power used was 19.25 kilowatt-hours, or 17.5 kilowatt-hours per 100 pounds of metallic material. The average power input was 28 kilowatts.

In this run 101.75 pounds of ingot and 1 pound of spillings were obtained, or 102.75 pounds of good metal. The slag gave 2.75 pounds of clean shot and iron borings; thus the total quantity of metal recovered was 105.5 pounds.

GENERAL RESULTS OF THE THREE HEATS.

After the furnace had cooled, 2.55 pounds of large manganese-bronze buttons with some iron borings and 9 pounds of the black powdery dross finer than 14-mesh were taken from the cold furnace. It does not seem probable that the dross, from the first or the second heats, that was not dislodged by scraping held metal from these two heats which was given up on the third, because the walls were scraped free of all material that would come off readily, and the pouring temperature of the third heat was more than 100° C. lower than those of the first two. Hence the recovery from the furnace obtained after cooling should probably be credited wholly to the first two heats, and mainly to the first.

All of the dross, 1.9 pounds from heat L39, 3.3 pounds from heat L40, and 9 pounds from the cold furnace, total 14.2 pounds, was mixed, sampled, and analyzed for copper and iron. It showed 22.3

per cent copper and 15.4 per cent iron. With 58 per cent copper in the manganese bronze, this composition corresponds to 5.1 pounds of manganese bronze and 2.2 pounds of iron. If heat L39 be credited, in addition to the dross skimmed off in that heat, with all the dross that was clinging to the furnace, the total quantity for that run is 10.9 pounds of dross, corresponding to 4.2 pounds of manganese bronze and 1.7 pounds of iron. Heat L40 would be credited with 3.3 pounds of dross, corresponding to 1.2 pounds of manganese bronze and 0.5 pound of iron.

Thus metal recoveries and losses for these three heats may be distributed as follows:

TABLE 3.—*Results of melting manganese-bronze borings in laboratory rocking electric furnace.*

	Heat No. L39.	Heat No. L40.	Heat No. L41.	Total.	Average.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*
Weight of material charged	120.0	120.1	109.55	349.65	
Metallic material in charge (oil free)	118.3	118.4	108.0	344.7	
Oil in charge	1.7	1.7	1.5	4.90	1.4
Good metal recovered:					
Ingot	105.35	109.20	101.75	316.40	90.5
Spillings	1.00	2.50	1.00	4.50	1.3
Total good metal	106.35	111.70	102.75	320.80	91.8
Bronze and iron shot recovered:					
Over 14-mesh in size	[a] 2.75	1.1	2.75	6.6	1.9
Under 14-mesh in size—					
Bronze	4.2	1.2	None.	5.4	1.5
Iron	1.7	0.5	None.	2.2	0.6
Total bronze and iron shot	8.65	2.8	2.75	14.2	2.1
	Per cent.	*Per cent.*	*Per cent.*		
Percentage of good metal	88.6	93.0	94.2		
Percentage of bronze and iron shot	7.1	2.4	2.5		
Percentage of oil	1.4	1.4	1.4		
Total proportion of original charge accounted for	97.1	96.8	98.1		
Volatilization loss (by difference)	2.9	3.2	1.9		

[a] 0.2 from dross; 2.55 from furnace cleanings.

In the preceding table the amount of shot, iron borings, and fine dross taken from the cold furnace has all been credited to heat L39, as the bulk of this material evidently came from the charge used in that run, and there is no way of telling how to apportion it among the different runs. However, from the difference in violence of "spitting" of zinc at the end of the heats, the loss from volatilization in run L39 was evidently larger than that in run L40, which in turn was larger than that in run L41.

To check these calculations, the ingots were analyzed for copper with results as follows: Heat L39, 61.8 per cent; heat L40, 60.1 per cent; and heat L41, 59.7 per cent. Let it be assumed that there was no mechanical loss of copper, and that the original borings were not sufficiently contaminated with yellow brass to raise their copper content above 58 per cent. Also, assume that the iron content was 1 per cent, which seems reasonable from the amount of mixed shot and iron recovered. Then the charge used in heat L39 contained

97.6 per cent manganese bronze, 1 per cent iron, and 1.4 per cent oil. As the charge weighed 120 pounds, there was 120 times 0.976, or 117.2 pounds of manganese bronze, and 117.2 times 0.58, or 68 pounds of copper in it. If the 61.8 pounds copper in the recovered alloy corresponds to 68 pounds, the weight of bronze recovered, figured from the analysis, would be (68 × 100) ÷ 61.8, or 110 pounds. Thus the zinc loss would be 7.2 pounds, or 6.15 per cent.

Similarly, in heat L40, the amount of manganese bronze in the charge was 120.1 times 0.976, or 117.3 pounds, and the amount of copper was 117.3 times 0.58, or 68.05 pounds. The recovery of bronze would be 68.05 ÷ 0.601, or approximately 113.5 pounds, showing a zinc loss of 3.8 pounds, or 3.2 per cent.

Likewise, in heat L41, the quantity of bronze in the charge was 109.55 times 0.976, or 107 pounds, and the amount of copper was 107 times 0.58, or 62 pounds. The amount of bronze recovered would be 62 ÷ 0.597, or 104 pounds, and the zinc loss would be 3 pounds, or 2.8 per cent.

The method of figuring losses by analysis is always unsatisfactory. For example, if there had been 5 per cent of 2.1 yellow brass in the original borings, the copper content of the charge in heat L41 would be calculated as follows: 5 times 66.6, or 3.33 per cent, plus the product of 95 times 58, or 55.1 per cent, making 58.43 per cent copper in the charge. Then the figures for heat L41 would become: 1.07 times 58.42 = 63.52 pounds of copper, and 63.55 ÷ 0.597 = 106.5 pounds of bronze recovered, showing a zinc loss of 0.5 pound or less than 0.5 per cent.

This calculation illustrates the closeness of analysis necessary for calculating losses by analysis.

It seems probable that the results obtained in heat L41, where 94.2 per cent good metal and 2.5 per cent mixed shot and iron, or a total of 96.7 per cent metallic material was recovered, which, allowing 1.4 per cent for oil content, shows a loss of 1.9 per cent metallic material, could be consistently duplicated or bettered with further practice.

Some of the same lot of manganese-bronze borings was melted in an oil-fired crucible furnace by the company, and gave the following results. For this part of the lot an oil determination showed 1.2 per cent.

Results of melting manganese-bronze boring in oil-fired crucible furnace.

	Heat 1.	Heat 2.	Average.	
	Pounds.	*Pounds.*	*Pounds.*	*Per cent.*
Oily borings charged	275	275		
Ingot recovered	235	231	233	84.7
Metal in skimmings	17	21	19	6.9
Oil in borings charged	3.3	3.3	3.3	1.2
Metal lost	19.7	19.7	19.7	7.2

Results with oil-crucible furnace and those with electric rocking furnace compared.

	Oil furnace.	Electric furnace.	
		Average.	Best.
	Per cent.	*Per cent.*	*Per cent.*
Ingot recovered	84.7	90.5	94.2
Total metal recovered	91.6	95.8	96.7
Oil content of charge	1.2	1.4	1.4
Metal lost	7.2	3.0	1.9

Although the results of heats L39 and L40 indicated that even when the furnace is rocked, local overheating can take place, those of heat L41 indicated that by using enough flux, keeping the charge far enough away from the arc, and rocking the furnace, local overheating can be avoided and low metal losses obtained.

It seemed probable from this test that more thorough stirring, such as would be obtained by giving the furnace a longitudinal as well as a circumferential motion, would be desirable.

The power consumption on the manganese-bronze runs in the electric furnace was as follows:

Results showing power consumption in melts of manganese-bronze borings in electric furnace.

[Furnace was cold at start.]

Item.	Heat L39.	Heat L40.	Heat L41.
Weight of charge, pounds	120	120	110
Time arc was on, minutes	54	39	41
Pouring temperature, °C	1,050	1,040	920
Average power input, kilowatts	41	38	28
Number of kilowatt-hours used	32	24.5	19.25
Power consumption, kilowatt-hours per 100 pounds of metallic material charged	26.6	20.2	17.5

TEST OF NICKEL BRASS.

Nickel brass, like yellow brass, is a rolling-mill alloy that is almost always melted in crucibles. The large zinc content causes, in general, a high metal loss, especially when the alloy is being made from new metals, for the melt has to be heated very hot to get the nickel to dissolve in the copper. On account of the high temperature, the crucible life is short.

The melting of nickel brass seems to offer a good field for the electric furnace, the advantages being, as in melting yellow brass, the possibility of saving zinc, the elimination of crucibles, and working with a large furnace, thus reducing labor costs. The saving in metal, the cheaper maintenance, and the lower labor cost should offset the increased fuel cost when using electric power instead of using coke, coal, or oil. In order to determine what results could be obtained, particularly as regards metal losses, in the laboratory electric furnace, about 300 pounds of nickel-brass scrap, consisting of about 18 per cent nickel, 56 per cent copper, and 26 per cent zinc, was obtained from the Riverside Metal Co. through the courtesy of Mr. W. W. Rogers, an official of the company.

This scrap consisted of defective pieces sheared off after some reduction from the original billet. The pieces were about 8 inches long, 1 inch thick, and varied from 1 to 5 inches wide, most of them being about 4 inches wide. They contained small pieces of charcoal, but were otherwise clean, and equivalent to ingot in remelting.

The company stated that in remelting this scrap the metal loss was 1.8 per cent, the fuel consumption was 40 pounds of coke per 175-pound pot (or about 23 pounds per 100 pounds of metal charged), and the No. 60 crucibles averaged 30 heats.

HEAT L42.

A trial heat of 50 pounds in the rocking arc furnace was first made. The run, started with a cold furnace, took 65 minutes and used 35 kilowatt-hours. The metal was poured at 1,100° C., which was too cold. There were recovered 48.65 pounds of ingot and spillings, and 0.8 pound of shot from the skimmings, or 49.45 pounds in all; hence the loss was 0.55 pound, or 1.1 per cent.

HEATS L43, L44, AND L45.

Then a series of three heats, the first one being started with the furnace cold, was run, with the following results:

Results of three heats on nickel brass.

	Heat No. L43.	Heat No. L44.	Heat No. L45.
Kind of charge [a]	Scrap (50.75), spillings (1.95), ingot from heat L42 (47.50).	Scrap	Scrap (96.7),[b] ingot (14.2).[c]
Total weight of charge, pounds	100.20	100.5	110.9.
Time arc was on, minutes	64	58	33.
Pouring temperature, ° C.	1,125	1,200	1,120.
Power consumption, kilowatt-hours	40	30.6	26.3.
Recovery:			
Ingot and spillings, per cent	98.3	98.6	107.2.
Shot from skimmings, do	0.9	0.4	2.0.
Total recovery of metal, do	99.2	99.0	109.2.
Loss	1.0	1.05	1.6.

[a] Figures in parentheses denote weight in pounds.
[b] Charged at start.
[c] Charged near end, to cool the melt.

Heat L43 was a little cold, the ingot being slightly "spilly"; heat L44 was just about right and gave good-looking ingot. In heat L45 the temperature was probably at least 1,250° C. and the pressure of the zinc vapor blew the furnace door loose. An ingot was put in to cool the melt, and cooled it too much. The higher zinc loss in heat L45 is due to this overheating. As soon as the furnace has been run long enough to show what power input is needed for each successive heat, overheating can be avoided.

One pound of a flux of broken glass with 10 per cent soda ash was used in each heat. Also charcoal was used in heat L42, but none was used in the other heats. The flux seemed to be a disadvantage rather than a help.

Excluding the results of heat L45, in which the melt was overheated, the average loss was 1.05 per cent; including it, 1.2 per cent. That is, the electric furnace should save three-fourths of 1 per cent of metal on this type of scrap. From results obtained with electric melting of yellow brass and manganese bronze, one would expect a still greater saving of metal in remelting borings, punchings, or other fine scrap in the electric furnace, as compared with fuel-fired furnaces.

EXPERIMENTS ON COPPER CASTINGS.

Some copper castings were needed for electrode holders on a large electric furnace, and in order to see whether a good quality of metal could be produced in the rocking furnace, the furnace was tried on copper.

The material was scrap copper wire and electrotypes, and as no boron suboxide or other similar deoxidizer was at hand, 1 per cent of zinc was added as a deoxidizer just before pouring.

HEAT L46 AND L47.

Two heats were made. In heat L46, 70 pounds was charged. The arc was on 55 minutes, and 32 kilowatt-hours was used. It took 13 minutes to spelter, pour two molds (the metal was poured direct from the furnace into the mold), and recharge.

In heat L47 the charge was 60 pounds. The arc was on 30 minutes, and 18 kilowatt-hours was used. The metal was poured at about 1,250° C. The power consumption on the first heat, starting with a cold furnace, was at the rate of 45 kilowatt-hours per hundredweight, and on the second, 30.

Two of the four molds, which were made in the Cornell foundry and brought to the laboratory, were not properly gated for pure copper. The castings from these two molds showed shrinkage at the gate, but were usable; the other two, from the properly gated molds, were good. The quality of the metal produced by the furnace was excellent, the castings being entirely free from porosity. The metal losses were not determined.

EXPERIMENTS IN MELTING ALUMINUM CHIPS AND INGOT.

Various heats were made in the laboratory rocking furnace remelting dirty aluminum chips. Such material has the peculiar property of compacting together when the melting point of the alloy is reached, and the finer globules formed by the melting of the smaller chips are prevented from coalescing by the coating of dirt. The mass of globules and dirt mats together and does not become fluid, hence rocking does not stir it properly. Puddling to break up this mass and promote coalescence is not practicable in an arc furnace, which should be run tightly closed. The use of large amounts of flux as an alternative means of promoting coalescence is practicable in crucible or reverberatory furnaces, but not in the rocking electric furnace. The cheapest suitable flux, salt and fluorspar, is volatile at the temperatures required for arc melting, but does not become fluid enough for stirring by rocking to cut down this volatilization. The flux is hard on most refractories. The results of heats L48 and L51 on these chips are recorded in detail (as runs 92 and 95) in a previous report on melting aluminum chips.[a]

To make melting of aluminum chips in the rocking furnace practicable, a graphite or graphite fire-clay lining would probably be needed, and a less volatile flux than salt and fluorspar would seem to be required.

Melting ingot or clean aluminum scrap in the rocking furnace is possible, but unless a superior quality of product can be obtained by electric melting neither the rocking furnace nor any other type of electric furnace can apparently compete, as regards costs, with oil or producer-gas fired iron-pot furnaces or open-flame oil or gas furnaces. In particular instances where fuel-fired furnaces give excessive heat, and consequently poor working conditions, the improvement in working conditions might warrant the use of an electric furnace.

The poor showing in electric melting of aluminum is due to the large amount of power required, and also to the fact that only a low temperature is needed, at which fuel-fired furnaces are relatively more efficient than at higher temperatures. In general, it is calculated[b] that 800° C. (1,475° F.) is about the lower limit at which electric furnaces normally begin to compete with fuel firing.

In order to find the power needed to melt an aluminum alloy in the rocking furnace, heat L52 was made, with an initial charge of 37 pounds of ingot consisting of 8 per cent copper and 92 per cent aluminum.

Starting with a cold furnace, it took 52 minutes heating and 30 kilowatt-hours to raise the charge to 735° C. Then 25 pounds more ingot was added, and 10 kilowatt-hours more was put in during 13 minutes. The charge was then at 870° C., or hotter than is needed for pouring aluminum castings.

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[a] Gillett, H. W., and James, G. M., Melting aluminum chips, Bull. 108, Bureau of Mines, 1916, p. 66.

[b] Johnson, W. M., and Sieger, G. N., Electric furnaces: Met. and Chem. Eng., vol. 11, 1913, p. 506.

Thus, it took a total of 40 kilowatt-hours to raise 62 pounds of aluminum to 870° C., and 10 kilowatt-hours to melt 25 pounds and heat it to 870° C. and also to raise the first 37 pounds from 735° to 870° C. This same furnace, starting cold, has melted 127 pounds of red-brass ingot and heated it to 1,140° C. with about 30 kilowatt-hours (Heat L34, p. —). After the furnace is hot, 15 kilowatt-hours has melted and heated to 1,220° C. 130 pounds of red-brass ingot (Heat L38, p. —).

That is, about twice as much power per pound of metallic material charged was required for heating the aluminum to its pouring temperature as for heating red brass to its pouring temperature. This result is in accord with the theoretical power consumption. Richards [a] has calculated that to raise aluminum to about 710° C. takes theoretically about 278 heat units, whereas to raise brass or bronze to about 1,050° C. takes only about 130 heat units. The difference is due to the extremely high heat of fusion of aluminum, the relative heats of fusion being as follows: Aluminum, 100; copper, 43; zinc, 23; tin, 14: lead, 4. This overbalances the higher temperatures needed for brass and bronze.

In the experiments described, the small laboratory furnace had given low metal losses on red brass, yellow brass of various contents of zinc, on red and yellow chips, manganese bronze chips, nickel brass, and has produced sound copper castings Considering the small size of the furnace, the power consumption was low. The electrode consumption was not excessive and the refractory lining stood up well.

The furnace would evidently work with fair efficiency on a 10-hour schedule, and could readily change from one alloy to another in successive heats. Hence, it seemed desirable to design and test out a larger furnace of this type.

EXPERIMENTS WITH LARGE ROCKING FURNACE.

DESIGN OF FURNACE.

Heats L39 and L41, on manganese-bronze borings, had indicated the desirability, in melting alloys high in zinc, not to overcharge the furnace or to over-power it, and had shown that the more thoroughly the charge was stirred by rocking the better. Therefore, two modifications of the type, one with a single rocking motion and one giving a doubly oscillating motion to the charge, were designed. These were patented and the patents [a] were assigned to the Federal Government, through the Secretary of the Interior as trustee, for the free use of the public. Should interested persons wish to work under these patents, licenses requiring no payment of royalty may be obtained from the Secretary of the Interior, by making application through the Director of the Bureau of Mines.

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[a] Richards, J.W., Electric power required to melt metals: Trans. Am. Brass Founders' Assn., vol. 4, 1910, p. 93.

ARRANGEMENTS FOR COOPERATIVE LARGE-SCALE TEST.

The Detroit Edison Co., Detroit, Mich., has for a long time been interested in the development of electric brass melting, and offered to cooperate in a test of a rocking furnace of commercial size. Mr. C. A. Weeks, the inventor of the Weeks zinc furnace, was invited by the Bureau of Mines and the company to participate in the test, but declined the offer.

Sketches of the furnace design were furnished by the bureau to the company; the latter refined the design, prepared the working drawings, made the parts for the furnace in its own shops and erected it. By the cooperative agreement, the expense of building the furnace and making the test was borne by the company, except for the salaries and expenses of the representatives of the bureau. By an arrangement between this company and the Michigan Smelting & Refining Co. of Detroit, the furnace was erected at the plant of the latter company; the furnace, electrodes, refractories, and power for the test were furnished by the Detroit-Edison Co., while the Michigan company furnished labor for lining the furnace, electrode cooling water, labor, accessories for pouring the metal, and supplied the metal melted.

During the earlier part of the test the charging and operating of the furnace was done by the bureau's representatives alone, later they were aided by a representative of the Detroit Edison Co., and at the end of the test the furnace was operated by a representative of the Michigan Smelting & Refining Co. The test was supervised throughout by the representatives of the bureau.

DESCRIPTION OF FURNACE.

Views of the furnace are shown in Plates II and III. Detail drawings are presented in Plate IV.

The furnace had a cylindrical iron shell 5 feet long by 5 feet in diameter, the drum being mounted within two steel rings These rings were combined tracks and gears, the track part resting on rollers for support and the gear part meshing with driving gears for rocking. At first the furnace was tilted within the gears for maximum stirring effect but after heat 77 it was set level.

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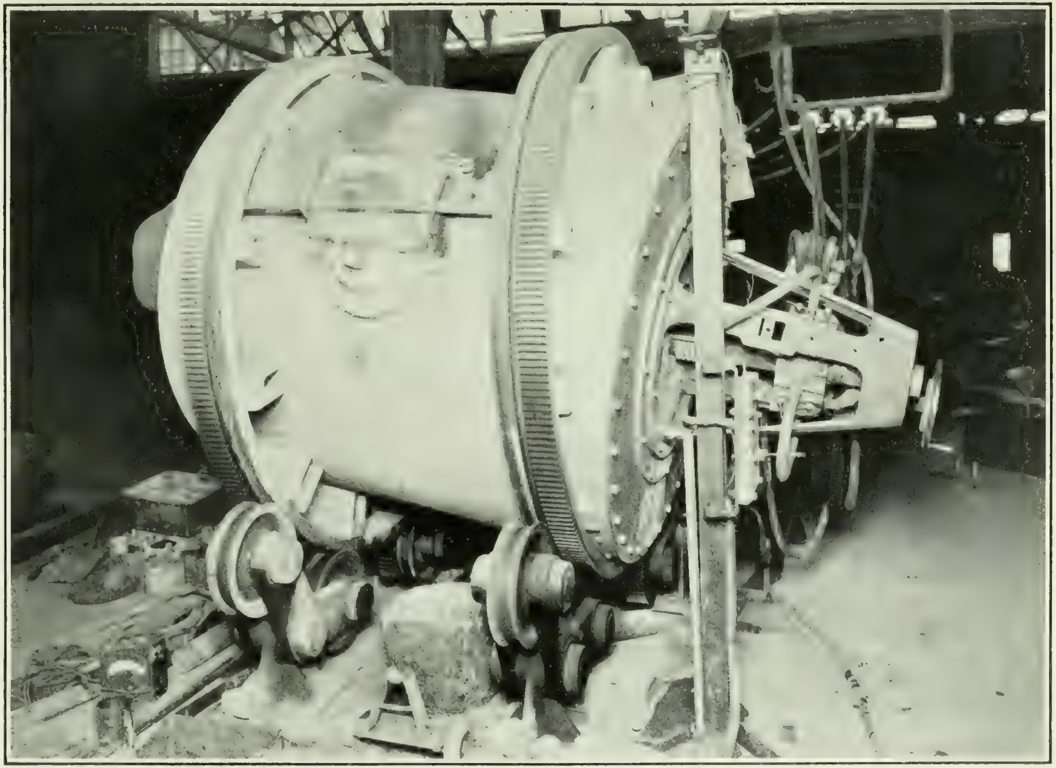
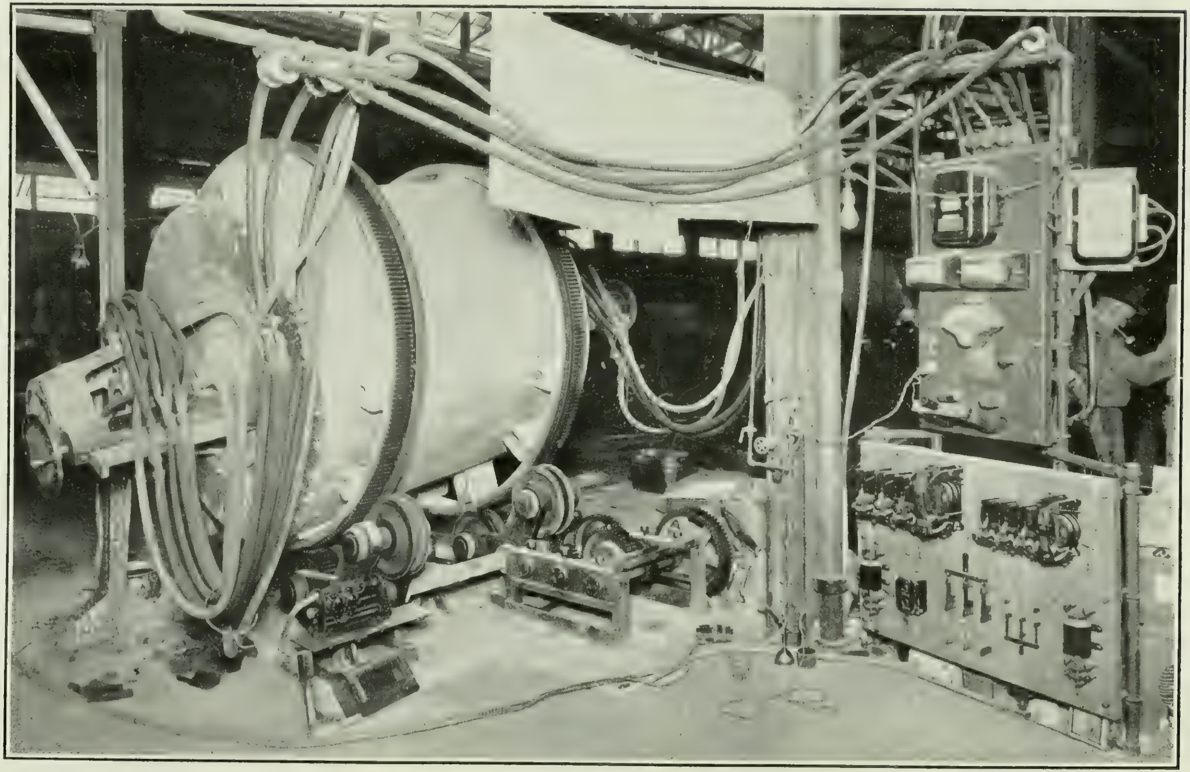
[a] Gillett, H. W., and Lohr, J. M., Electric furnace, U. S. patent 1201224, Oct. 10, 1916: Gillett, H. W., Electric furnace, U. S. patent 1201225, Oct. 10, 1916.



LARGE-SIZE ROCKING ELECTRIC BRASS FURNACE. SHOWS CHARGING DOOR AND ADJUSTABLE ELECTRODE HOLDER.



LARGE-SIZE ROCKING FURNACE. SHOWS ELECTRICAL CONNECTIONS, SWITCHBOARD, AND MOTOR-CONTROL DEVICES.

Graphite electrodes passed through the central part of each end of the drum. The electrode holders were adjusted by handwheels actuating a screw that moved a sliding support of the lathe type. Regulation of the arc was by hand, no automatic regulator being used. The single-phase arc was between the tips of the two electrodes.

The charging opening, 15 inches long by 10 inches high, was closed with a plug-type door lined with 4½ inches of "corundite" brick. The door had flanges seating on the shell and conforming to its contour, and was held in place by a transverse bar. The door was not hinged to the shell, but was removed by a chain hoist working on a small jib crane whenever the furnace had to be opened. Below the door was a pouring spout 2 inches wide and 1½ inches deep, which was closed with a brick plug. Both door and spout were luted in place with fire clay. The door did not have to be removed for pouring.

ROCKING AND POURING.

Through an automatic device, the furnace could be rocked by a motor back and forth about 80° from an extreme position at which molten metal would not quite run into the spout. A complete oscillation, from one extreme point to the other and back to the first, took 13½ seconds. This was called the "safe rock" (see fig. 1), and was begun when approximately one-half the power input needed for any heat had been used; it swashed the unmelted material about in the molten part and tumbled the solid material over, so that fresh surfaces received the direct radiation from the arc. The angle of rocking is so small that solid material does not drop onto the electrodes and break them. As soon as most of the charge is melted, so that electrode breakage will not ensue, the angle of rocking is increased through the controlling device to "full rock," about 200°. One limit is the same as on the "safe rock"—that is, where the molten metal will almost run into the spout—and the other is where the molten charge almost reaches the charging door. Thus all of the hearth circumference is washed by the molten metal, except the 10-inch height of the charging door plus a few inches each side of it. A complete oscillation on "full rock" takes 33½ seconds.

By turning a handle on the controlling apparatus, the angle of rocking can be made anything between about 80° and about 200°. It is desirable to increase the angle of rocking from time to time during the heat, so as to wash the walls and stir the metal as much as possible without danger to the electrodes from solid material falling on them.

Thus the part of the hearth that serves as a roof when the furnace is stationary is subjected to continuous direct radiation from the arc only while the metal is being melted, and while the heat capacity of the charge is still high. The roof then gives up its excess heat to

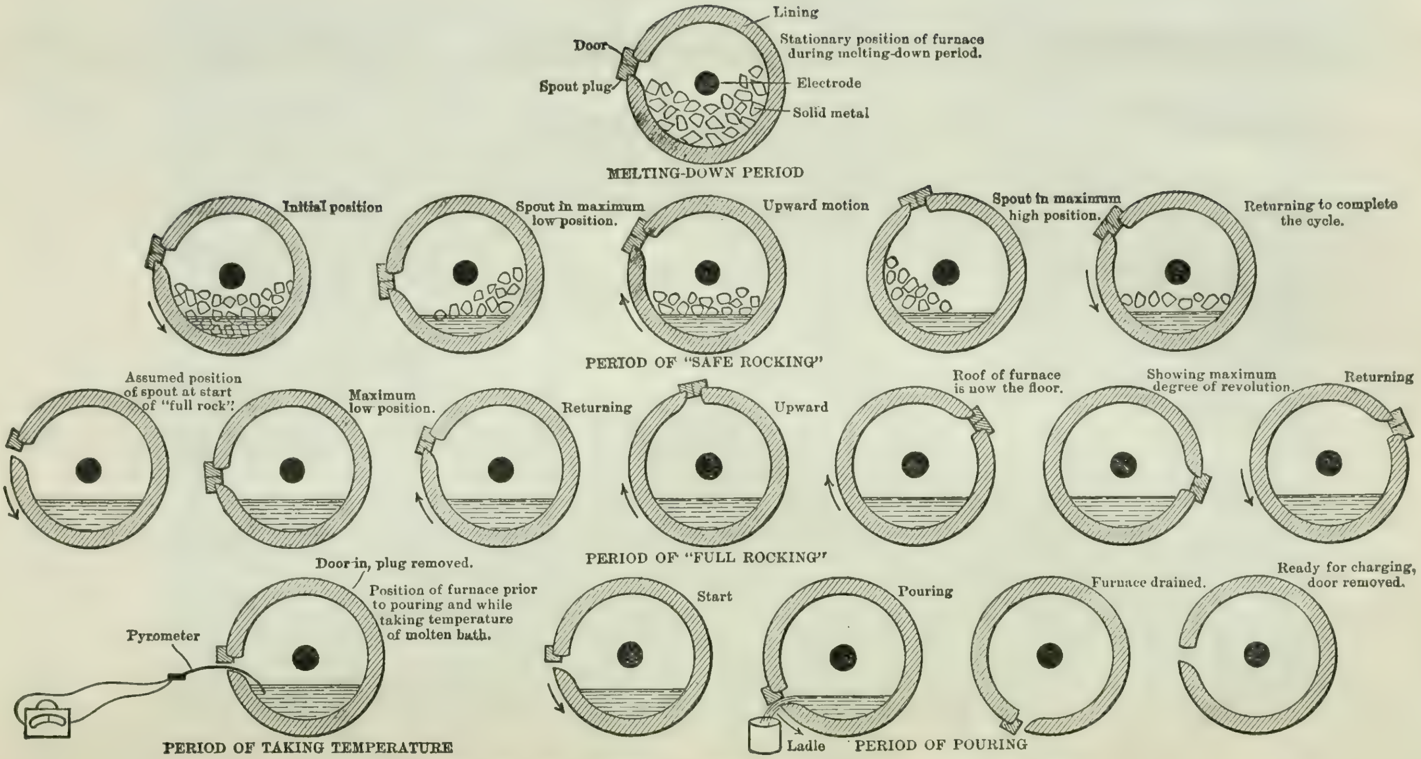
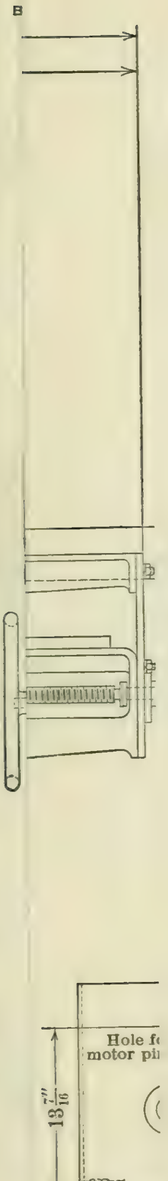
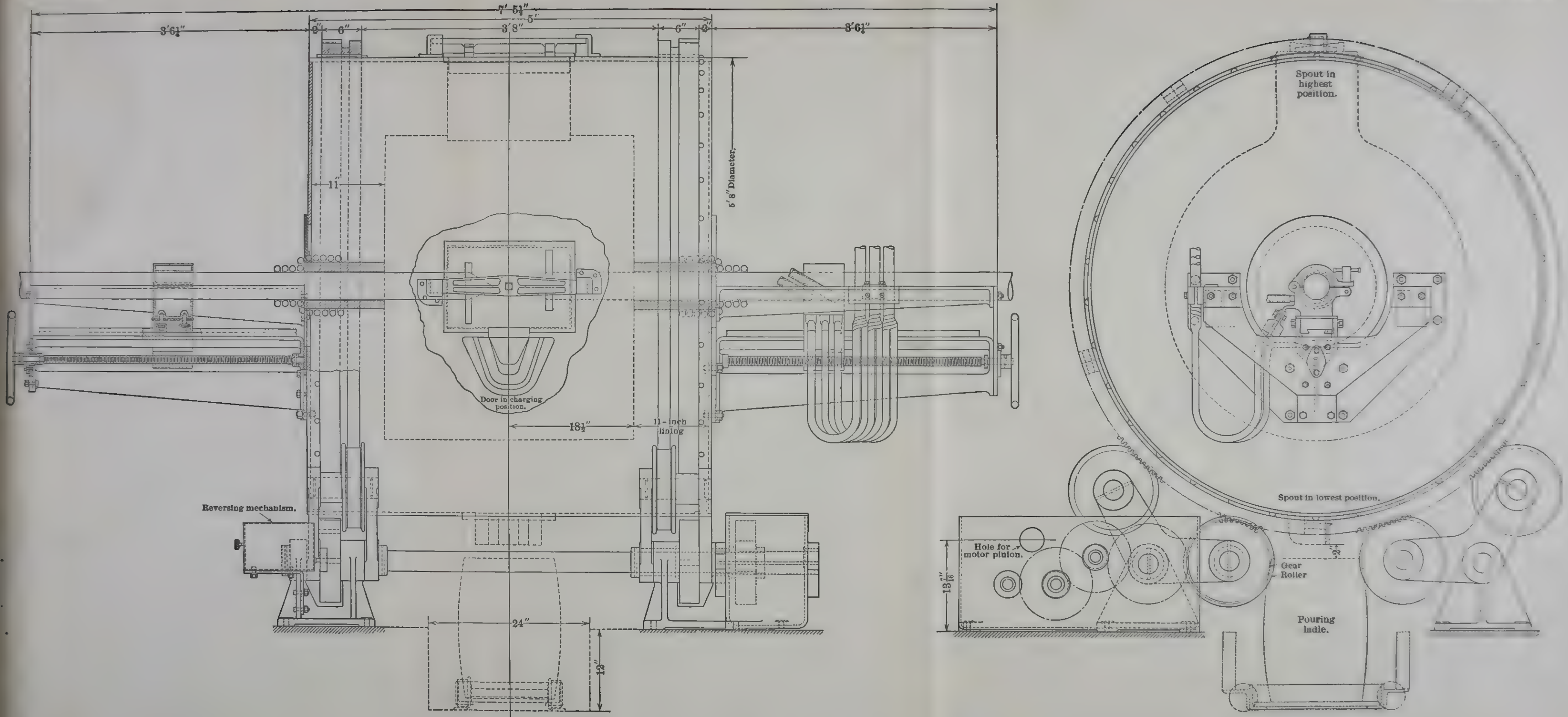

Lining
Stationary position of furnace during melting-down period.
Door
Spout plug
Electrode
Solid metal
MELTING-DOWN PERIOD
Initial position
Spout in maximum low position.
Upward motion
Spout in maximum high position.
Returning to complete the cycle.
PERIOD OF "SAFE ROCKING"
Assumed position of spout at start of "full rock".
Maximum low position.
Returning
Upward
Roof of furnace is now the floor.
Showing maximum degree of revolution.
Returning
PERIOD OF "FULL ROCKING"
Door in, plug removed.
Position of furnace prior to pouring and while taking temperature of molten bath.
Pyrometer
PERIOD OF TAKING TEMPERATURE
Start
Pouring
Ladle
Furnace drained.
Ready for charging, door removed.
PERIOD OF POURING

FIGURE 1.—Diagrams showing positions of furnace during melting, rocking, and pouring.



REVISED.



GENERAL ASSEMBLY OF ROCKING ELECTRIC BRASS FURNACE AS REVISED.

the molten metal that washes it, and at the end of the heat is no hotter than the metal.

In an unrocked furnace the heat stored in the roof at the end of a melt will raise the temperature of the metal for some time after the power is cut off. In a rocked furnace the hearth and the metal are kept at the same temperature and the charge does not get hotter after the power is off, so that control of the pouring temperature can be much closer.

The rocking also stirs the metal thoroughly and thus prevents the superheating of the top of the melt that results in an unrocked indirect-arc furnace.

Thus rocking accomplishes four important results, as follows:

1. Prevents surface superheating and consequent zinc losses.
2. Thoroughly mixes the metal.
3. Cools the refractory lining to the temperature of the metal, thus increasing the lining life and decreasing the radiation losses and hence the power consumption.
4. Makes close temperature control possible by minimizing the storage of heat.

The rocking was by an 11-horsepower alternating-current motor, but tests showed that a 5-horsepower motor would be ample. For pouring a portable reversing switch, with leads incased in flexible metallic tubing, allowed the operator to pour from a position where he could readily see the stream and the inside of the ladle. By cutting the automatic rocking device out and the pouring switch in, the spout could be depressed past the limiting position for rocking and the metal could be poured.

Both rocking and pouring were controlled by solenoids at the switchboard, the solenoids actuating two contactors which made and broke the motor circuit, thus running the motor and turning the furnace in either direction.

The automatic control for the rocking mechanism was designed and built by Mr. Oliver Marsick, of the Detroit Edison Co., to meet the specifications prepared by the Bureau of Mines' representatives, and worked very satisfactorily. Ordinary care must, of course, be taken to keep all electrical contacts clean.

A small buggy, running on a track laid beneath the furnace, held the ladle during pouring.

REFRACTORY LINING.

The furnace had an inner layer of "corundite" 4½ inches thick, laid in "corundite" cement, this layer being brought out to the shell about the door and the electrodes. Back of this was a 4½-inch layer of "heat insulating" brick, laid in asbestos cement, and back of this a 3-inch layer of infusorial-earth brick and infusorial-earth cement.

This gave a lining 12 inches thick, leaving the hearth chamber 36 inches long and 36 inches in diameter.

In the ends 8-inch holes were left in the corundite for the electrodes. These holes were lined with a 2-inch layer of alundum cement to prevent current leakage through the hot brickwork.

The furnace would normally be rated at 1,500-pound capacity. It will take 2,000 pounds and has been operated with that charge, though the usual charge was 1,300 to 1,320 pounds, this being used instead of 1,500 pounds because the crucibles used as ladles held 650 to 660 pounds and the 1,300 to 1,320 pound charge just filled two ladles.

ELECTRODES.

The electrodes, 4 inches in diameter, were of Acheson graphite with threaded nipples for continuous feeding. Electrodes 5⅛ inches in diameter were first tried, but were found unnecessarily large. Also, 4-inch electrodes with male and female joints were tried, but were less satisfactory than those with the nipple joint. It was found advisable, in order that successive sections should be properly gripped by the electrode holders and should fit the electrode openings closely, to machine the electrodes to $4 \pm \frac{1}{16}$ inches in diameter. The electrodes as received varied in diameter and many were far from straight.

At first the 4-inch electrodes were not water cooled; they became so highly heated that they burned away a little just outside the furnace. Then water-cooled brass sleeves were used; these were later discarded for a simple coil of ½-inch diameter copper pipe, having six turns, the inner two turns being 6 inches in inside diameter, embedded in the alundum cement, and the outer four being 4¼ inches inside diameter, the coils being separated about ¼ inch. Water was passed through the electrode holder, thence to the coils and then to the outlet. The flow of water through the holders and coolers of both electrodes varied from 1½ to 3 gallons per minute, and the heat thus abstracted amounted to between 6 and 10 kilowatts, averaging about 7½ kilowatts per hour while the furnace was in operation. The electrodes when thus cooled would stand an average of 2,000 amperes, with a short-time maximum of 2,500 amperes and an instantaneous maximum of 4,000 amperes, without any trouble from overheating.

POWER SUPPLY.

Power was taken from one phase of the Detroit Edison 3-phase, 60-cycle, 4,600-volt circuit. Two hundred and twenty volts was tried on the furnace in heats 1 and 2 at the start of the test, without reactance, and again in heats 219 and 220 later in the test, with reactance. However, even with the reactance the arc was uncontrollable at this voltage and drew 3,000 to 4,000 amperes, or 500 to 600 kilowatts. Also, 105 volts was tried, without reactance, in heats 3, 4, and 5, but did not give a high enough power input, so the voltage was changed to 131 volts on open circuit during heats 6 to 218, inclusive. Three 100-kilovolt-ampere transformers were used to step the current down from 4,600 to 110 volts; the voltage was then boosted to 131 volts with a 50-kilovolt-ampere transformer. From heats 221 to 249, inclusive, 127 volts was used, and from heats 250 to 301, 117 volts. The furnace was found to work satisfactorily at any voltage between 115 and 140 volts.

The transformers could not be placed close to the desired position of the furnace, and the secondary leads ran about 75 feet from transformers to switchboard. On each side of the circuit four 500,000-c. m. cables were used, or in all about 600 feet of cable. No reactance other than that inherent in the furnace leads and transformers was used in heats 1 to 77. In these tests, made before an external reactance was added, the power factor would start at about 65 with a cold furnace, rise promptly to 85, and then increase to more than 90 as the furnace became hot. Most of the time the power factor was 90 to 95 on the basis of instantaneous readings, or 90 to 99 by a power-factor meter.

In order to stabilize the arc, make it require less attention from the operator, and reduce surging, an external reactance was used after heat 78. This reactance was made of four turns of a pair of 750,000-c. m. cables, the turns being 14 inches in diameter, with about 250 pounds of laminated iron strips, 2 by 19 inches in size, held in a bag tied within the turns. This crude reactance reduced the current on dead short circuit from about 13,000 amperes without it to 4,000 amperes with it. The voltage across the arc and the reactance under full load averaged about 115, the current varying from about 1,500 to 2,000 amperes. The power factor of the furnace, plus reactance, taken on the secondary side averaged about 85 (instantaneous readings), while that on the primary side (power-factor meter) averaged about 77.

The power factor was high enough to avoid a power-factor penalty and to be satisfactory to the central station. The taking of an average load of 200 kilovolt-amperes off one phase of the three-phase circuit was not objectionable to the power company. The substation operator could tell whether the furnace had current on or not, but it did not disturb the voltage control of the circuit enough to inconvenience other customers on the same line.

SWITCHBOARD AND METERS.

The switchboard was placed about 6 feet back of the furnace, where the meters were readily visible to the operator. It carried an integrating watt-hour meter readable to 1 kilowatt-hour, for the furnace circuit, connected on the secondary, and another similar meter for the motor circuit.

Also, a voltmeter, an ammeter reading to 3,000 amperes, and a watt meter reading to 300 kilowatts were placed in the secondary circuit. A main switch on the secondary circuit was provided at the switchboard, and an oil switch and circuit breaker were placed in the primary circuit back of the transformers. The switchboard also carried the solenoids, contactors, and switches for the motor circuit for rocking and pouring.

FLEXIBLE LEADS.

Three 500,000-c. m. cables, one on each side, were run from the switchboard to points above and slightly back of the furnace, and from these, six 300,000-c. m. flexible brush-holder cables in about 9-foot lengths brought the current to each electrode. The flexible cables were allowed just enough sag to permit their reaching easily in all positions of the furnace without at any time touching the floor.

These cables were clamped rigidly to a framework about the electrodes, thus taking the strain off the electrode, and enough slack was left between the point at which they were clamped and the electrode holder to permit moving the electrode in and out freely.

COST.

On the basis of cost of the experimental installation the Detroit Edison Co. calculates that, with the experience gained in this test, a complete furnace of this size, including transformers and switchboard, could be erected, at early 1918 prices for materials, for about $5,000. License to use the Bureau of Mines patents, of course, involves no royalty. This cost is low compared with the prices of most electric brass furnaces of corresponding sizes that are on the market, but, of course, does not include any manufacturer's profit, payment for expenses incurred in development of the furnace, or salary and expenses of a skilled operator to start the furnace and instruct the buyer in its operation, which are legitimately included in the prices of electric furnaces of other types.

PLANT CONDITIONS.

The Detroit Edison Co. chose to install the furnace at the plant of the Michigan Smelting & Refining Co., because of the proffered cooperation of that firm, which makes a wide variety of alloys.

This plant does no sand casting, but does a general refining business, and its brass foundry makes ingot to standard composition, or to the purchaser's specifications. The raw material used is mainly borings, ingot from the reverberatory refining furnaces, and copper, lead, tin, and brass scrap of various kinds. The borings are mechanically mixed with great care, are passed through magnetic separators, and a sample pot is carefully run down and analyzed. The reverberatory ingot is also analyzed, and the charge is calculated on the basis of the analysis. Rapid check analyses are made on the first heat of any new charge to verify the calculation. Drillings are taken from an ingot from each pot poured, and the drillings from a number of pots are mixed to give a composite sample, which is then analyzed to prove that the product is within the specified limits of composition.

The borings are with few exceptions very oily, rarely carrying less than 3 per cent oil and often 6 per cent. Some of the copper used is ingot from the reverberatory furnaces, some is sheared heavy scrap, but most of it is skeleton copper or wire "cabbaged" into bundles in a hydraulic press. Also short lengths of copper pipe and punchings are sometimes used.

Another material is "sweated" and "cabbaged"—old automobile-radiator sections. In making yellow brass a good deal of nickled brass, plumbing fixtures, pipe, thermos bottles, shaving-soap boxes, etc., and much "medium brass," such as cornets, cuspidors, automobile hub caps, etc., are used.

Such material is charged without bundling and is extremely bulky. This material and the cabbaged copper wire often carry considerable nonmetallic material, and the borings often contain dirt and nonmetallic material other than oil or moisture.

In the regular shop practice the charge is melted in coke fires, using No. 250 crucibles with a capacity of 650 pounds of red brass or 600 pounds of yellow brass. At the time of the test these crucibles cost $37.50 each and lasted, on an average for different lots and makes, four to nine heats, averaging probably not more than six heats. Crucibles bought before the war cost $8 each and lasted 18 heats.

In an attempt to eliminate the use of crucibles open-flame furnaces had been installed, but the production in these furnaces, from scrap and borings, of alloys containing much zinc or lead has been found impracticable. Ingot for railroad "brasses," that is, a bearing bronze with 12 per cent or more lead, was made in large amount during the period of the test, but such ingot could not be produced from scrap charges in the oil furnaces because of the loss of lead and the variable composition resulting therefrom.

The management considered that from the raw material used practically nothing but a true bronze could be made in the oil furnaces. These furnaces were not run during the period when the electric furnace was being tested, both of them, in fact, being removed to make room for other apparatus.

The coke fires average three heats in 10 hours. One furnace tender handles three furnaces; the coke and the charges are brought to him, and the pot is pulled by an electric hoist and is poured by a pouring gang.

The metal is poured into molds on a conveyor and, after freezing as it runs along the conveyor, is dumped into water.

The larger chunks of metal are handpicked from the skimmings, and these, with the drippings and spillings made while the pot is being poured, and any ingot, obtained from the last metal in the pot, that is below standard size, as well as metal recovered from the ashes when a pot breaks, if such recovered metal is not materially altered in composition, are fed back into subsequent pots having charges of the same composition.

The skimmings and ashes, together with any spilling that has become mixed in composition through failure to clean the drip pans at the proper time, are sent to the crushing and concentrating plant, and the concentrate is fed to the reverberatory furnaces.

As the three melts of a day's run in any one furnace may differ in composition and adjacent furnaces may run different compositions at the same time, the recovery from ashes and skimmings can not be allotted among the different alloys made, and the true net melting losses are never known.

Neither was it possible even to estimate, from the records available, what the average recovery from the ashes and skimmings was on the foundry output as a whole during any given period.

Since only the gross and not the net coke-fire losses were ascertainable, in the electric furnace tests the same procedure was followed. Large chunks of metal were picked from the skimmings, the metal spilled during pouring was swept up, pouring drip was recovered from the drip pan where practicable—in most tests the operator was too busy charging the next heat to scrape up the drip from the electric-furnace ladles, and it went back to the coke fires with the regular foundry drip—and these, with any small ingots from the tail of the ladle, were fed back into other charges of the same composition. The electric furnace often ran only one or two consecutive heats on the same composition, whereas the coke fires usually ran a larger number. The result was that in comparing gross losses the electric furnace was at a disadvantage on single heats or short runs where spillings, drippings, and short-weight ingots could not be fed back. Hence, in the figures following, the net loss with the electric furnace is more nearly comparable to the gross loss with coke-fired furnaces than the gross electric-furnace losses are, when that furnace made short runs and the coke furnaces made a large number of pots.

In pouring the pots the loss of drip, when not fed back, averaged 0.27 per cent on 424 pots and was the same in pouring from the electric as from the coke furnaces.

The usual crucibles, more or less preheated in a coke fire, were used as ladles for the electric furnace. They were often cold and as a result sometimes became skulled to some extent. The skulls were sometimes recovered, but often the foundry needs when a pot broke would require shifting the skulled pot to a coke fire, so that some skulls were not credited to the electric-furnace metal-loss account.

Using graphite crucibles as ladles is an expensive and unsatisfactory procedure. Clay-lined, iron ladles and suitable oil or gas-fired preheaters should be provided.

It is necessary to point out these sources of inaccuracy in the metal-loss comparison, because the plant conditions made it impossible to get true net losses in either type of furnace. The borings were often analyzed for oil content, but the exact content was difficult to estimate and varied widely, owing to oil soaking down to the bottom of the pile of borings. The large amount of oil and the unascertainable amount of nonmetallic material other than oil made the true metallic content of the charge doubtful. The only reliable figures are the gross weight of charge, this including oil and dirt, and the weight of good ingot obtained. The ingot weights did not always check exactly on different scales, although the scales were constantly tested and adjusted, and the tares of the skids on which ingot was trucked and weighed would vary from those marked. In the long run, however, the figures for gross metal loss may be taken as giving a true comparison between the gross losses in the two furnaces.

It should be emphasized that the figures given for gross loss include oil and dirt and do not show the true loss of metal in either furnace, being much higher because of the high nonmetallic content of the charge. They merely give the comparative results in the two types of furnace when melting on the same dirty, oily material.

DELAYS.

More time was required for charging bulky materials like borings and "cabbaged" scrap than would be required with all ingot or heavy scrap. To facilitate the charging of bulky material, the door should be larger and it should be possible to draw the electrodes back entirely into the walls so the charge can be thrown in instead of having to be placed carefully. For 1,300-pound charges of such material a slightly larger shell and hearth would be of advantage.

Time was also lost in pouring, because it was often necessary to wait 10 minutes to half an hour for the crane to be free. Usually only one ladle was used and the furnace had to stand idle while the first ladleful was being poured and the ladle brought back. Having two hot ladles in waiting in order to empty the furnace promptly would have saved much time. Also, a larger spout would have permitted a bigger stream and more rapid pouring.

Even under the most favorable conditions met in the tests, the delays in charging and pouring were excessive. In 5 days of 10 hours, 27 heats of 1,300 pounds each were made. Of the 50 hours the arc was on only 32 hours, or 64 per cent of the time, whereas 18 hours or 36 per cent was spent in charging and pouring.

With the improvements for quicker charging and with suitable facilities for rapid discharging, one more heat per day—that is, six or seven heats, depending on how bulky the charge is—should be made in 10 hours, instead of five or six. This would decrease the average power consumption about 3 per cent, because an added heat at the end of the day is made with the furnace hot and in the condition to melt at highest efficiency.

EFFECT OF OIL IN THE CHARGE.

Another source of delay was the time required for burning off the oil in the borings. Centrifuging the borings, thus recovering the oil, or still better, briquetting them under heavy pressure so as to squeeze out the oil and make them compact enough to charge like ingot would save much time in charging. When the borings are very oily, or charged in large quantities, the oil is not driven off rapidly. While the oil vapor is in the furnace the arc will not hold properly, as oil vapor is not a good electrical conductor.

Neither can the furnace be sealed tight until practically all the oil is burned off, on account of the pressure of the vapors. Hence, in using oily borings, if the furnace is not hot already, it should be preheated empty till the walls are hot. Then the borings are charged. With the door out to let the oil escape, the furnace is rocked a few minutes until the oil is nearly all burned off, when the rest of the charge is added.

It might be worth while to insert a pipe, carrying an air blast, into the furnace for a few moments after oily borings are charged, in order to burn the oil more quickly and within the furnace where some of the heat of combustion would be absorbed, rather than to burn the distilled oil outside the furnace.

Preheating for the first heat in the morning can be avoided by charging the borings or the entire charge after the last heat on the previous day, while the furnace is still hot.

In the tests, the average weight of borings and their average oil content was such that almost always at least one gallon, and often three, of oil had to be driven off.

The oil vapor gives a reducing atmosphere in the furnace while charging, prevents oxidation of the electrodes, and the vapors driven off last carbonize, thereby producing soot that serves for charcoal, no charcoal being required. However, if too much soot is permitted to form, the soot is likely to entrain metallic shot and thus cause too high a gross metal loss.

METHOD OF CHARGING.

It was found desirable to place the whole charge in the furnace at the beginning, rather than to melt part of it, open the furnace, and add the rest. In a furnace that is not sealed, and is open to the air or in one that can be provided with a loosely-fitting, quick-acting door, part of the charge can be melted and the rest added from time to time in small portions that will not freeze the metal already melted. But in melting alloys high in zinc or lead, an open furnace means a high volatilization loss, and the rocking furnace, which gives a means of reducing this loss, should as much as possible be run sealed tight. Hence frequent charging in small portions will not work as well, though some classes of material are so bulky that the charge must be added in two or three portions. If, say, half the charge is melted and then the rest added, the cold charge may, especially if made up of large ingot, freeze the whole into one solid slug, which is very hard to melt and which is likely to be rocked through the full arc too soon and thus fall on the electrodes and break them.

When the charge is largely light scrap, like cuspidors, etc., it can be piled up above the electrodes and in contact with them, as its weight is not sufficient to break them. The current is then thrown on with the primary oil switch, and any electrical connection between the electrodes (previously separated) is at once burnt out by the momentary short circuit. With ingot or cabbaged scrap, such connection can not be permitted, as it causes too heavy a short circuit.

When ingots, or large and heavy "cabbages" of bundled scrap are being charged, the use of a suitable charging paddle for placing the charge properly was found desirable. The pieces could be placed exactly where wanted, and time was saved.

For a long time the lead was added at the end of the heat. This necessitated opening the door, adding the lead, closing the door, and rocking to mix the metal. Later it was found that there was no loss of lead and no segregation if the lead were added with the main charge; and, still later, adding zinc with the main charge was found to be desirable. Knowledge of various small details like this, such as knowing when it is safe to increase the rocking arc, when enough oil has been driven off, so that the spout can be luted with clay and stay tight and so that the soot will not entrain an excessive amount of metal, when to reduce and when to increase the flow of electrode cooling water, etc., is readily gained by experience in operating the furnace.

TEN-HOUR OPERATION.

Throughout the test on 10-hour operation, except for four or five nights early in the test, the furnace was not heated at night, either by electricity or otherwise. Putting coke in at night was tried, with admission of various amounts of air, but proved to do more harm, through coke and ash being stuck to the lining by slag, than the small amount of heat developed did good. The furnace was run 10 hours or less, as the foundry did not run at night and it was impossible to arrange for pouring until the latter part of the second test, which will be described later. In comparing the power-consumption figures for the rocking furnace, run on a 10-hour schedule, with those for other furnaces run on a 24-hour schedule or kept hot at night by power, this fact should be kept in mind.

ELECTRODE CONSUMPTION.

The actual electrode consumption was 16.3 pounds for 21,660 pounds of material melted, or 1½ pounds (about 20 cents at normal or about 40 cents at early 1918 prices) per ton. The loss from accidental breakage, after experience had been gained, was small. In heats 96 to 218—122 heats, 102 on 1,300 to 1,320 pound charges, and 20 on 600-pound charges—there were nine breakages in melting 144,000 pounds, or 1 for each 8 tons. Four of these were from starting the "safe" rocking too soon, and five from hitting the electrode in charging bulky material.

In the latter event the breakage was usually only a nipple. Broken pieces may often be reused by machining, or may at least give enough stock from which to make a nipple. Breaking in charging can be avoided by so arranging the electrodes that they can be drawn into the refractory lining. In estimating the probable cost for electrodes in such a furnace, an allowance for loss through breakage equal to the actual consumption will certainly be ample.

LINING LIFE AND COST.

The "corundite" brick and cement for the inner layer of one lining cost about $100; the "heat insulating" brick and asbestos cement for the middle layer cost about $150. The infusorial-earth brick and cement for the outer layer, and the alundum cement about the electrodes, cost about $50. Thus the total cost for refractories was $300.

It took a furnace mason and two helpers about five days, that is, a total of 150 man-hours, to line the furnace. Much of this time, however, was spent in chipping the heat-insulating brick from standard to wedge shape, and much more in deciding just how the brick had best be laid to give maximum strength, the mason changing the plan several times, tearing out and relaying the ends and the part about the door. With all brick of proper shape and with a complete lining diagram to go by, 100 man-hours should suffice.

At the end of heat 71, when some 70,000 pounds had been melted, the following record was entered in the notes—"lining shows no wear except at roof, and there barely appreciable."

Between heats 71 and 72, in the absence of the operator, some one experimented with the pouring switch, turning the furnace past the pouring point, tightening up the flexible leads, and running the gear of the automatic rocking control device against a stop, bending part of the control so it had to be removed for repair.

While this part was being repaired, it was necessary to rock the furnace by hand in heats 72 to 77, comprising about 8,000 pounds. No rocking was done in these heats till about 150 kilowatt-hours had been put in, and the rocking was not as continuous thereafter as when done mechanically. In some of these heats with the furnace stationary, the power input was held steady for some time at 250 kilowatts, which is well above the normal power input. In heat 77, some of the lining fell from the "roof." A spot about 15 inches by 24 inches in size, in the center of the roof part was worn away to 1 inch thick, the thickness tapering from this point to the original 4½-inch thickness on the hearth part. About two-thirds of the corundite lining was removed and replaced with new brick, the hearth being left intact. The layer of heat insulating brick, thus bared, was in good condition. The corundite ends showed traces of wear, and part of one brick had come off. Aside from the patching of this place the ends were not touched.

The cost of relining the roof part was about $30 for corundite brick and cement, plus wages for 30 man-hours—1½ days—for mason and helper, tearing out and relining. At about heat 177 there was a little more wear visible at the patched place on the end. This was on the original lining. The new roof part showed no wear at this time. Some lining seemed to be slagging off about heat 177 but this ceased entirely about heat 183.

At heat 193, the furnace mason inspected the lining and pronounced it to be good for an indeterminate period. After heat 218, when about 240,000 pounds had been melted, the whole lining appeared in good shape, the roof being still good, the original hearth as good as ever, and the ends still good, though showing some wear. With heat 218, the first test proper was completed. It was desired, however, to see whether the use of 220-volt current, with the reactance, was possible. The arc was found to be uncontrollable, and the power input was 500 to 600 kilowatts, or three times the normal. This caused failure of part of the roof. During rocking, much metal soaked into the openings thus made, for the metal losses were high on the 220-volt heats.

When the roof was repaired after heat 77 a layer of brass was found between the corundite and the heat-insulating bricks, except on the very top of the roof part. A thin sheet-iron liner, inserted between these two layers when lining up, should stop the flow of brass through the joints and prevent it from penetrating farther, thus reducing the amount of metal lost into the lining, preserving the outer layers intact, and reducing the heat loss from radiation by preventing soakage of metal into the brick beyond the corundite layer.

Evidently the failure of the roof at heat 77 was due to lack of sufficient rocking in heats 72 to 77, perhaps combined with too high a power input in those heats. The original roof failed after 78,000 pounds were melted, the power input in that time being enough to melt 100,000 pounds, if the furnace had been run steadily and at full output instead of on an experimental basis. The second roof was still good after about 160,000 pounds more, equivalent to about 200,000 pounds if the furnace had been run steadily, had been melted. The hearth and ends were still good after melting 238,000 pounds, equivalent to 300,000 on steady running. The cost of relining, using corundite, should be well under 40 cents per ton when the metal is poured at 1,150 to 1,200° C. If the furnace is to be used for delivering metal at 1,250 to 1,300° C. the roof part of the hearth and the upper part of the ends would probably last longer if constructed of zirkite, carborundum, or some other more refractory material, although these have drawbacks. Silica brick might serve in a furnace working 24 hours a day, but spalling of the bricks on cooling might prevent their use in a furnace working on a 10-hour schedule.

BEHAVIOR OF THE ARC.

As previously noted, when the arc was in series with sufficient reactance, surging was reduced and the stability was increased. With reactance any arc voltage from 105 to 140 volts, open current, or 95 to 125 volts under load, gave a well-behaved arc. On 220 volts, open current, with the amount of reactance used the arc was uncontrollable and had to be run at a very high current in order to make it hold, causing the power input to be far too high.

Within the range of suitable voltages the arc is "snappy" when the furnace is cold and will not give the normal power input until the inside of the lining is at low red heat. If the door is not tightly sealed, so that the gases can escape readily, the "snappiness" in the cold furnace is vastly increased, the arc apparently being blown out by the rush of gas. But when the furnace is at full running temperature the arc will run smoothly and quietly, even if the furnace is not tight. With the furnace hot and tightly sealed, the arc can not be heard.

The presence of a nonconducting vapor, such as oil vapor, makes the arc hard to hold. When oil is being driven off from an oily charge, there is a well-defined point at which the arc suddenly "catches" and begins to hold steadily, this being coincident with a sudden drop in the volume of the oil flame from the open spout and in the emission of soot.

Zinc vapor also has a marked effect on the arc. If an alloy of high zinc content is being melted and rocking is not started early in the heat, there comes a time when the arc suddenly takes a higher current and has to be lengthened in order to decrease the current and to keep the power input normal. The natural tendency is to draw the electrode out rapidly and too far, thus causing the arc to break. If rocking is started, the arc at once becomes normal, because when the charge is stirred less zinc vapor is produced and the superheating of the surface layer is prevented. If the angle of rocking is kept small, the phenomenon will be repeated at the point at which the roof begins to reflect heat more rapidly than the metal can absorb it, so that the surface again becomes superheated. Then, if the full rocking angle is used, the heat in the roof is taken up by the metal, stirring is again sufficient, and the arc becomes steady. Still later, in melting an alloy very high in zinc, the arc again shows signs of unsteadiness as the charge approaches the pouring temperature, because zinc vapor is then being given off from the thoroughly stirred charge and not merely from a surface layer. The unsteadiness increases with rising temperature. At about this time a tiny zinc flame may break through the luting of the door or, if the electrodes do not fit tightly into their holes, zinc flame may escape about the electrodes. The flame may or may not appear, according to the tightness of the electrodes and the door, but the behavior of the arc is a good guide as to whether or not a charge high in zinc has reached the proper pouring temperature.

For melting ordinary red brass the length of the arc at the end of the heat is normally about an inch, although it can be made longer or shorter without greatly affecting the power input. For alloys high in zinc the arc draws out to a length of 2 or 3 inches at the end of the heat and must be held at the proper length within more narrow limits. If the arc is too short, too high power will be drawn, and if the proper length is exceeded the arc breaks. On 220 volts the arc was drawn out at the end of the heat of yellow brass to more than a foot, giving too high a power input at any length short of that at which the arc would break.

The behavior of the arc in zinc vapor is what one would expect of an arc in a vapor that is a good electrical conductor, although some authorities state that zinc vapor is a poor conductor.

In melting alloys containing no zinc the arc is so short that the proper length is somewhat hard to maintain—the limits of a short circuit from one electrode to the other and of no circuit at all being close together—which again indicates that the zinc vapor, at least in low concentrations, acts as a good conductor. For alloys without zinc the use of a little flux—such as soda ash, common salt, or fluorspar—which will give off well-conducting vapors seems to aid in maintaining a stable arc. Flux does not have much effect on alloys very high in zinc, the arc acting about as it does in zinc vapor alone.

HEAT RETENTION.

When the furnace is running on a 10-hour basis and the last heat of the day's run has been poured at 1,150° C., the empty hearth will be at red heat, about 625° C. (1,150° F.), or more on the next morning after standing 14 hours. If the furnace is kept closed it will be at about 100° C. after standing 48 hours. By taking out the door and the electrodes, the furnace would be cool enough for workmen to go inside for relining in about 60 hours. The time required for cooling could be reduced by blowing in air.

LACK OF STORED HEAT.

At the end of a heat, after the furnace has been rocked through the "full angle" of rocking, when the arc is stopped the temperature of the metal remains practically stationary, falling at the rate of about 2° to 3° C. per minute. By running the arc a couple of minutes every 10 or 15 minutes the metal can be kept molten for an indefinite period.

OUTPUT AND LABOR COST.

The furnace can be operated by one man, aided about one-third of the time by a helper in charging, the charges being delivered to the furnace and taken away by a separate pouring gang, as is done in attending to the coke-fired furnaces. In a 5-day, 50-hour, run on red brass or leaded bronze, half of which was on very bulky charges, 35,184 pounds was heated to an average temperature of 1,175° C. (2,150° F.). Thus the output of the rocking furnace, at 66⅔ hours total labor, was about 525 pounds per man-hour. The coke-fired furnaces produced 5,850 pounds from three furnaces in 10 hours. One furnace tender can attend the three furnaces, and at least 1½ hours of a helper's time is required in wheeling coke, taking out ashes, and seeing to the recovery of metal from ashes. Therefore the output is 5,850 pounds for 11½ man-hours, or about 510 pounds per man-hour.

It would be feasible to attach a motor to one electrode adjusting screw and control that electrode with an automatic device, such as the well-known Thury, Turnbull, or Seede regulators used on steel furnaces. Whether this procedure is advisable or not depends on conditions at any specific plant. If several furnaces were in use, automatic control would probably decrease the labor cost by reducing the number of skilled operators required. As the addition of an automatic control to the experimental furnace would have increased the cost of installation, and was not essential in a test to show the possibilities and limitations of the furnace, it was not tried. Use of such control would tend to hold a slightly higher power input and hence to decrease the power consumption and increase the output.

The operation of the rocking furnace requires a different and perhaps higher order of intelligence than the coke-fired furnaces, but the working conditions, through the elimination of the laborious work of charging coke and poking metal over the hot coke fire, are much superior. If male labor were provided for pouring, charging, and for replacing the electrodes if they should break, a girl could operate the furnace readily.

All in all, the labor cost per ton of output will not be any higher for the electric rocking furnace than for coke-fired furnaces.

CHARACTER OF METAL PRODUCT.

No difficulty was found in draining the furnace completely when changing from one alloy to another; that is, a charge is not contaminated by metal remaining from a previous charge of different composition if the furnace is properly drained and scraped.

No sand castings were made, nor were any physical tests made of the metal produced. All the metal melted was poured into ingot and went into the regular output of the plant. No ingots were rejected on inspection except in two melts. In one of these, a ladle of metal was not properly skimmed and dross fell on the ingot in pouring, giving a surface smooth in spots instead of uniformly rough. The ingots were melted again and poured with proper skimming and were then satisfactory. Another ladle was poured into new, cold molds, and the resulting ingots were rough. When remelted and poured into properly prepared molds, the ingots were satisfactory. In neither instance was the trouble due to the quality of metal produced.

On an alloy of 73 parts Cu, 4 Sn, 20 Pb, 3 Zn, the ingots were rather better as regards uniformity of lead content and freedom from "lead sweating" than were those from the coke fires.

Frequent analyses of the electric-furnace product were made at the start by the Michigan Smelting & Refining Co. laboratory. However, the chief chemist soon found that the results were uniform and showed less variation from the calculated composition than the metal from the coke fires, stated that the extra analyses were unnecessary, and requested that they be discontinued. Thereafter the electric output of any alloy was sampled as a part of the regular foundry output, analysis being of mixed samples from the electric and coke fires, except when some special information was desired.

The following examples are characteristic:

Characteristic analyses of samples.

Heat Nos.	Source.	Composition.			
		Copper.	Tin.	Lead.	Zinc.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
13–17	Composition sought	76	8	13	3
	Electric-furnace product	75.9	8.3	13.1	2.7
20–24	Composition sought	76	8	13	3
	Electric-furnace product	76.2	8	12.4	3.2
28–30	Composition sought	85	5	5	5
	Electric-furnace product	85.2	4.9	4.8	5
33–34	Composition sought	83	4	6	7
	Electric-furnace product	82.9	4.4	5.7	6.9
40–44	Composition sought	67	1	2	30
	Electric-furnace product	66.6	1	2	30.4
	Coke-furnace product	68.4	0.5	1.7	29.3
69–70	Composition sought	68	1	7	24
	Electric-furnace product	67.9			
	Coke-furnace product	69.9			
321	Composition sought	60	0	3	37
	Electric-furnace product	59.8			
322	Composition sought	60	0	3	37
	Electric-furnace product	59.7			
323	Composition sought	60	0	3	37
	Electric-furnace product	59.7			

METAL LOSSES.

As stated before, the metal-loss figures are merely comparative, the charges being oily borings and more or less dirty scrap, the actual metallic content of which was never exactly known.

In Table 4 the metal losses are given in the order in which the heats were made.

TABLE 4.—*Data on metal losses.*

Heat No.	Alloy.				Red borings.	Yellow borings.	Ingot.	Cu.	Pb.	Other material.		Total weight charged.	Weight of good ingot.
	Cu.	Sn.	Pb.	Zn.						Kind.	Weight.		
					Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*		*Lbs.*	*Lbs.*	*Lbs.*
1, 4–7	65½	....	2	32½	......	1,111	1,785	......	......	....	.....	2,896	....
2–3, 8–11	83	7	4	6	1,400	.....	2,465	......	......	....	.....	3,865	....
12–24	76	8	13	3	1,800	.....	5,955	2,900	1,150	....	.....	11,805	11,371½
25–27	85	5	5	5	2,720	42	......	1,120	26	....	.....	3,908	3,645
28–30	85	5	5	5	......	.....	3,704	......	......	....	.....	3,704	3,635
31	84	8	4	4	......	.....	1,288	......	......	....	.....	1,288	1,268
33–34	83	4	6	7	1,620	280	600	80	40	....	.....	2,620	2,393
35	76½	8½	12½	2½	230	.....	720	254	106	....	.....	1,310	1,319
32–36–44	67	1	2	30	......	4,000	896	......	......	Fixtures Nickled brass Radial or sections Zinc	1,600 1,200 800 42	8,538	8,008
45–53	84	7	8	1	11,600	.....	......	......	......	....	.....	11,600	11,126
60	76	8	13	3	200	.....	860	230	......	Fixtures	30	1,320	1,236
62–63	76	8	13	3	......	.....	......	......	......	....	.....	2,624	2,549
64	90	6½	1½	2	400	.....	......	840	......	Fixtures	64	1,304	1,220
65	80	1	8	11	70	210	210	125	37	....	.....	652	610
61, 66–70	68	1	7	24	100	2,210	360	333	134	Fixtures Foundry scrap	100 181	3,326	3,083
71–77	78	3	7	12	4,560	868	......	1,458	150	Yellow brass	2,108	9,144	8,866
78, 79	66	5	26	3	412	.....	660	......	224	....	.....	1,306	1,196
80–86, 89–92	73	4	20	3	3,298	.....	7,800	434	1,682	Yellow tubing	688	14,392	13,918
87–88	72½	6½	17½	3½	500	.....	1,640	28	280	.....do	124	2,612	2,576
93	84	4	4	8	400	146	360	400	......	....	.....	1,306	1,264
94–98	76	8	13	3	1,000	.....	4,500	600	110	Yellow tubing	320	6,530	6,294
99–110	72½	6½	17½	3½	4,800	.....	7,080	2,344	1,600	Fixtures	24	15,668	15,104
111–127	67	1	2	30	......	5,600	......	......	......	.....do Nickled brass Grindings (dust)	3,400 1,400 400	10,800	9,935
128–129	76	8	13	3	1,370	20	870	758	348	....	3,266	3,266	3.232
130–131	83	4	6	7	1,000	320	720	572	......	....	.....	2,612	2,410
132–136	84	4	4	8	3,000	900	......	2,430	120	Babbitt borings	100	6,550	6,147
137–141	85	5	5	5	3,150	400	......	2,840	140	Foundry scrap	46	6 576	6,361
142–153	78	2	10	10	2,520	.....	......	9,120	1,372	Fixture Babbitt	4,400 40	15,840	15,346
154–155	83	4	6	7	1,200	.....	960	104	100	Yellow clipping	212 40	2,616	2,427
156–157	84	4	4	8	1,200	.....	960	68	60	.....do	292 40	2,620	2,508
158–161	67½	4	26½	2	340	.....	2,040	1,552	1,244	Babbitt	40 48	5,224	5,080
162	83	4	6	7	690	.....	......	400	50	Yellow clipping	164	1,304	1,251
163	84	6	10	....	400	.....	......	752	102	Babbitt	52	1,306	1,265
164–166	85	5	5	5	2,100	.....	720	918	66	Yellow clipping	120	3,924	3,638
167–173	68	1	7	24	......	2,625	......	805	210	Fixture Babbitt	700 56	4,396	4,003
174–182	79	9	10	2	6,300	.....	3,780	478	644	Tin Babbitt	264 324	11,790	11,515
183–186	67½	4	26½	2	1,720	.....	960	1,720	1,240	....	.....	5,240	5,148
187	67½	4	26½	2	......	.....	......	......	......	....	.....	....	....
188–189	84	6	10	....	800	.....	......	1,528	200	Babbitt	80	2,608	2,524
190	85	5	5	5	......	.....	1,829	(*c*)	(*c*)	....	.....	....	1,839
191	71¼	1¾	6	21	360	450	240	30	34	Fixture	200	1,314	1,149
192–193	85	5	9	1	1,200	.....	480	880	8	.....do	60	2,628	2,528
194–206	79	9	10	2	......	.....	11,520	4,602	1,170	Babbitt	260	16,952	16,492
208	87½	5½	7	....	......	286	......	950	28	.....do	40	1,304	1,219
207, 209–218	84	6	10	....	5,500	.....	2,640	5,544	616	....	....	14,300	14,041

[a] Not run.

[b] Gain.

REMARKS.

Heats 1, 4–7.—Loss includes soakage into fresh lining.
Heats 12–24.—Lead had 2 per cent nonmetallic content.
Heats 33–34.—Three per cent nonmetallic content; spilled badly in pouring.
Heat 35.—Furnace not drained after heat 35.
Heats 32, 36, 44.—One pot spilled badly.
Heat 60.—Ladle would not hold all the metal.
Heats 62, 63.—Details of charge not recorded.
Heat 65.—Ladle would not hold all the metal.
Heats 61, 66–70.—Borings very oily.
Heats 78, 79.—Lining partly new; high loss from soakage.
Heats 94–98.—Two hundred and thirteen pounds of skimmings, of unknown metallic content, and one heavy skull were not counted.
Heats 111–127.—All skull; spill and drip not recovered; 12½ per cent oil in grindings.

TABLE 4.—*Data on metal losses*—Continued.

Gross loss.		Coke-fire loss on same charge.		Recovered metal, small ingot spill, etc.	Total weight of metal recovered.	Net loss not deducting oil and dirt.		Percentage of oil in borings.		Loss on sample pot borings.			Weight of charge less oil.	Net loss on charge, less oil.	
Pounds.	Per cent.	Per cent.	Number of pots.			Pounds.	Per cent.	Yellow.	Red.	Yellow.	Red.	Weight of oil in borings.			Net loss.
					Lbs.					*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*	*P.ct.*
......	......	(*a*)	......	......	2,699½	196½	6.5	4.0	......	......	......	42½	2,851½	152	5.3
......	......	(*a*)	......	......	3,753½	111½	3.0	......	4.5	......	......	63	3,802	48½	1.3
433½	3.7	4.0	......	122½	11,494	311	2.6	......	1.0	......	......	41	11,764	277	2.4
263	6.7	8.4	......	41	3,686	222	5.7	3.0	......	12.7	5.2	......	......	......	1.7
69	1.8	(*a*)	......	6	3,641	63	1.7	......	......	......	......	......	......	......	......
20	1.5	(*a*)	......	3	1,271	......	1.3	......	......	......	......	......	......	......	1.3
237	9.0	6.6	......	127	2,520	100	3.8	4.0	3.0	......	......	74	2,546	26	1.0
[b] 9	[b] 8.7	4.1	......	11	1,330	[b] 20	[c] 1.5	......	3.0	......	......	6	1,304	[b] 26	[b] 2.0
530	6.6	8.0	3	64	8,072	486	6.0	4.0	......	9.9	......	160	8,478	[b] 326	[b] 3.9
474	4.1	7.0	125	50	11,176	424	3.7	......	1.5	......	......	174	11,426	2.50	2.2
84	6.4	6.3	79	51	1,287	33	2.7	......	......	......	......	......	......	......	......
75	2.9	10.7	......	23	2,572	52	2.0	......	......	......	......	......	......	......	......
84	6.4	7.3	40	43	1,263	41	3.1	......	......	......	......	......	......	......	......
42	6.4	14.1	11	40	650	2	0.3	......	......	......	......	......	......	......	......
243	7.5	9.3	11	68	3,151	175	5.3	......	......	......	......	......	......	......	......
278	3.0	5.9	17	84	8,950	194	2.1	......	......	......	......	......	......	......	......
110	8.4	2.7	93	29	1,225	81	6.2	......	......	......	......	......	......	......	......
474	3.3	3.7	220	54	13,972	420	2.9	......	......	......	......	......	......	......	......
36	1.4	4.2	78	......	......	......	......	......	......	......	......	......	......	......	......
42	3.3	(*a*)	......	10	1,274	32	2.5	......	......	......	......	......	......	......	......
236	3.6	3.9	30	184	6,478	52	0.8	......	......	7.7	3.7	......	......	......	......
564	3.6	3.7	147	70	15,174	494	3.2	......	......	......	......	......	......	......	......
865	8.0	(*a*)	......	56	9,991	809	7.5	5.0	......	......	......	330	10,470	479	4.6
34	1.1	5.5	90	15	3,247	19	0.6	......	......	......	4.0	......	......	......	......
202	7.7	6.0	6	......	......	......	......	......	......	......	4.0	7.5	......	......	......
403	6.1	3.4	27	......	......	......	......	......	......	......	3.0	7.5	......	......	......
215	3.2	4.6	30	......	......	......	......	......	......	......	3.0	5.7	......	......	......
494	3.1	7.1	34	......	......	......	......	......	......	......	3.6	......	......	......	......
189	7.7	7.2	58	55	2,482	134	5.1	......	......	......	......	8.1	......	......	......
112	4.3	6.5	72	17	2,535	95	3.6	......	......	......	......	8.1	......	......	......
144	2.8	3.0	56	18	5,098	126	2.4	......	......	......	......	2.1	......	......	......
53	4.2	6.4	48	......	......	......	......	......	......	......	......	6.1	......	......	......
41	3.1	4.0	39	......	......	......	......	......	......	......	......	6.1	......	......	......
286	7.3	5.9	39	100	3,738	186	4.7	......	......	......	......	6.1	......	......	......
393	8.8	6.7	35	72	4,075	321	7.3	......	......	......	5.8	......	......	......	......
275	2.3	3.6	109	25	11,540	250	2.1	......	......	......	4.0	......	......	......	......
92	1.7	3.6	82	......	......	......	......	......	......	......	5.3	......	......	......	......
......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
88	3.4	3.2	......	60	2,584	28	1.1	......	......	......	2.5	......	......	......	......
(*d*)	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
165	12.6	6.6	70	108	1,257	57	4.3	......	......	......	6.0	6.4	......	......	......
100	3.8	3.5	102	9	2,537	91	3.4	......	......	......	......	......	......	......	......
460	2.7	3.1	112	......	......	......	......	......	......	......	......	......	......	......	......
85	6.5	(*a*)	......	......	......	......	......	......	......	......	......	......	......	......	......
259	1.8	2.4	103	......	......	......	......	......	......	......	......	......	......	......	......

[c] Plus a little dirty scrap.

[d] Charge was all ingot from coke fires that would not pass requirements on acoount of lead segregation. Passed after being melted in electric furnace. Charge not weighed.

REMARKS—Continued.

Heats 128–129.—Spill and skull not recovered.
Heats 130, 131.—Spill and skull not recovered; ingots counted up shy.
Heats 132–153.—Twenty-three pounds of dross, containing some metal, was not counted.
Heats 156, 157.—Large slug.
Heats 158–161.—No ladle drip recovered.
Heats 164–166.—Skull metal included in 185 pounds; skimmings not included.
Heats 167–173.—Borings oily, from bottom of pile.
Heats 174–182.—Some of the drip, spill, etc., was not recovered.
Heats 183, 186.—No drip, etc., recovered.
Heats 189–193.—Skulls and drip not included; 86 and 84 per cent Cu ingots mixed in shipping room; heavy skulls, cold ladles.

TABLE 5.—*Metal losses in electric-rocking furnace and in coke-fired furnaces compared.*

Reference No.	Heat Nos.	Cu.	Sn.	Pb.	Zn.	Weight charged.	Gross loss, electric furnace.	Net loss[a] electric furnace.	Foundry gross loss, same charge.	Excess gross loss of coke over electric melting, or savings by electric on gross loss.		Excess gross loss of electric over coke melting.		Off-weight ingot and slugs.[b]	Recovered spill and drip not fed back.	Ladle skulls, approximate weight.	Skimmings containing machine metallic shot.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Pounds.*	*Pounds.*	*Per cent.*	*Per cent.*	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1	64	90	6½	1½	2	1,304	6.4	3.1	7.3	0.9	12	....	....	40	3	....	....
2	25-27	85	5	5	5	3,908	6.7	5.7	8.4	1.7	62	....	....	15	23	....	....
3	137-141	85	5	5	5	6,576	3.2	....	4.6	1.4	92	....	....	....	....	....	....
4	164-166	85	5	5	5	3,924	7.3	4.7	5.9	....	....	1.4	55	....	....	[c] 100	138
5	192-193	85	5	9	1	2,628	3.8	3.4	3.5	....	....	0.3	8	....	....	....	[d] 19
6	45-53	84	7	8	1	11,600	4.1	3.7	7.0	2.9	336	....	....	14	36	....	....
7	163	84	6	10	....	1,306	3.1	....	4.0	.9	12	....	....	....	....	....	....
8	188-189	84	6	10	....	2,612	3.4	1.1	3.2	....	....	.2	5	....	....	[c] 60	....
9	207, 209-218	84	6	10	....	14,300	1.8	....	2.4	.6	86	....	....	....	....	....	....
10	132-136	84	4	4	8	6,550	6.1	....	3.4	....	....	2.7	177	([e])	([e])	([e])	[f] 238
11	156-157	84	4	4	8	2,620	4.3	3.6	6.5	2.2	57	....	....	11	....	....	....
12	130-131	83	4	6	7	2,612	6.0	....	7.7	1.7	43	....	....	....	....	....	....
13	154-155	83	4	6	7	2,616	7.7	5.1	7.2	....	....	.5	13	[g] 58	....	....	....
14	162	83	4	6	7	1,304	4.2	....	6.4	2.2	29	....	....	....	....	....	....
15	65	80	1	8	11	652	6.4	.3	14.1	7.7	41	....	....	40	....	....	....
16	174-182	79	9	10	2	11,790	2.3	2.1	3.6	1.3	153	....	....	....	25	....	....
17	194-206	79	9	10	2	16,952	2.7	....	3.1	.4	62	....	....	....	....	....	....
18	142-153	78	2	10	10	15,840	3.1	....	7.1	4.0	631	....	....	....	....	....	....
19	71-77	78	3	7	12	9,144	3.0	2.1	5.9	2.9	265	....	....	10	14	[c] 60	....
20	12-24	76 76½	8 8½	13 12½	3 2½	11,805	3.7	2.4	4.0	.3	34	....	....	11	48	[c] 63	....
21	60	76½	8½	12½	2½	1,320	6.4	2.7	6.3	....	....	.1	1	[g] 45	6	....	....
22	62-63	76½	8½	12½	2½	2,624	2.9	2.0	10.7	7.8	204	....	....	15	8	....	....
23	94-98	76½	8½	12½	2½	6,530	3.6	.8	3.9	.3	.19	....	....	55	25	[c] 104	....
24	128-129	76½	8½	12½	2½	3,266	1.1	.6	5.5	4.4	143	....	....	....	15	....	....
25	80-85 89-92	73	4	20	3	14,392	3.3	2.9	3.7	.4	57	....	....	9	43	....	....
26	87-88	72½	6½	17½	3½	2,612	1.4	....	4.2	2.8	73	....	....	....	....	....	....
27	99-100					15,668	3.6	3.2	3.7	.1	15	....	....	....	70	....	....
28	191	71¼	1¾	6	21	1,314	12.6	4.3	6.6	....	....	6.0	79	[h] 68	....	[i] 40	....
29	61, 66-70	68	1	7	24	3,326	7.5	5.3	9.3	1.6	53	....	....	41	37	....	....
30	167-173	68	1	7	24	4,396	8.8	7.3	6.7	....	....	2.1	93	[h] 62	10	....	....

31........	158-161	67½	4	26½	2	5,224	2.8	2.4	3.0	.2	10	....	....	....	18	....	....
32........	183-186	67½	4	26½	2	5,240	1.7	....	3.6	1.9	99	....	....	....	....	....	....
33........	36-44	67	1	2	30	7,200	[j]5.2	5.1	8.0	2.8	201	....	....	....	9	....	....
34........	78-79	66	5	26	3	1,306	[j]8.4	6.2	2.7	....	....	5.7	75	25	4	....	....
Total.....	....	....	....	....	....	204,461	....	....	....	....	2,792	....	506	519	394	427	....

2,792 — 519
506 — 394
— 427

Net saving on gross loss, 2,286 pounds=1.15 per cent.
1,340 Scrap recovered, 1,340 pounds=0.65 per cent.

Total saving, 3,626 pounds=1.8 per cent.

[a] Recovered spillings, drippings, and small ingot, that is, all pourable metal, credited; no allowance made for oil, dirt, or metal recoverable from skimmings.

[b] Light or excess weight ingots and slugs, poured into "niggerhead" in draining furnace when ladles would not hold all the metal not fed back.

[c] Ladle cold.

[d] Much metal shot in dross.

[e] Weight not obtained.

[f] Much dross from carbonization of oil, held up metal shot.

[g] Ladle would not hold all the metal.

[h] Ladle would not hold all the metal, heavy skull in cold ladle.

[i] Ladle would not hold all the metal; borings, 60 per cent of charge, were from bottom of pile and were much more oily than the borings used in the coke-fired furnaces.

[j] These two heats were made immediately after partial relining, and the loss represents soakage into the fresh lining.

In Table 5 have been collected the results of runs on material which was also melted in the Michigan Smelting and Refining Co. coke-fired furnaces. These alloys have been arranged in order of copper content and for each alloy that was made from a different lot of raw material separate entries have been made. Each entry, then, may be considered as the result of a separate test of the electric furnace, as compared with the coke-fired furnaces, on a definite charge. Of the 34 tests the electric furnace shows a lower gross loss, or difference between weight of charge and weight of good ingot, in 25 tests and the coke-fired furnace in 9 tests. Of the 9 tests, in those designated by reference Nos. 4, 8, 13, 21, and 28, the excess loss is due to the ladles being so cold as to skull badly or not being large enough to empty the furnace completely, neither condition being the fault of the furnace. Among the other four tests are the two designated Nos. 5 and 11, in which the excess loss in electric melting compared with coke melting is due to the retention of metal in dross. With a little more experience such losses could doubtless be reduced. In the test designated as reference No. 30 the larger part of the excess loss is offset by metal poured out because the ladle would not hold it all, and the rest, about 0.7 per cent, is accounted for by the fact that the borings used were very oily. The top of the pile had been run in the coke-fired furnaces, leaving the bottom borings, into which oil had run down, for the electric furnace. The oily condition of the borings is reflected in the high gross loss figures in both types of furnace. In the test designated as reference No. 34 the excess loss is due to soakage into a fresh hearth. However, without making any allowance for the exceptions mentioned, on 102 tons the electric furnace returned 2,286 pounds, or 1.15 per cent more good ingot than the coke fires.

On account of the many short runs in the electric furnace, the small ingot and metal poured into "niggerhead" because the ladle would not hold it all could not always be fed back into the furnace. In regular operation such metal would be fed back at once or stored for future use, and would not be a loss. The same applies to the spillings. With properly preheated ladles skulling would be reduced to a minimum. The 1,340 pounds of small ingot, "niggerhead," slugs, spill, and skull not fed back would raise the savings—as compared with coke-fired furnaces—to 3,626 pounds, or 1.8 per cent. This does not include any metal that had soaked into the hearth and would be recovered when the lining was torn out.

Even in the longer runs with the coke fires a certain amount of drip from pouring the last pots was not fed back, and hence is not credited to the coke fires in the above tabulation. But in many of the electric-furnace runs there was pouring drip which was not fed back, skulls not credited, etc., so that the above comparison is fair.

It is noteworthy that the comparisons where the coke fires showed a lower gross loss were all with the shorter runs in the electric furnace, where inability to feed back the scrap affects the figures most. In no instance of a run of 7,000 pounds or more did the electric furnace fail to show a lower gross loss.

Of course, in this comparison the amount of metal recoverable from the ashes of the coke fires is not taken into account. However, as such metal has to be put through the concentrating plant and then smelted for copper content, its amount balanced against the cost of its recovery and the loss of metals other than copper will by no means make up for the balance in favor of the electric furnace.

Broadly speaking, the higher the zinc content of the alloy, and the larger the proportion of borings in the charge, the greater is the metal saving in electric melting compared with melting with coke fires.

RUNS ON EXTRUSION METAL.

It would seem logical, then, to attempt to extend the application of the rocking furnace to rolling-mill alloys, such as cartridge and shrapnel brass, extrusion metal (a brass from which extruded shapes are made), etc., and to manganese "bronze," the latter containing about 42 per cent zinc.

Through the courtesy of the Detroit Copper & Brass Rolling Mills, which supplied the material, a few heats (Nos. 54–59) were made on extrusion metal, with 36½ per cent zinc. As the results of these tests showed a distinct limitation in the furnace as at first designed and operated, they are described below.

RAW MATERIAL.

The raw materials were rod ends containing Cu 61, Zn 36.5, and Pb 2. 5 per cent; "sawdust" (saw cuttings) containing Cu 60, Zn 38.5, and Pb 1.5 per cent, with 4 per cent water from cutting compounds; copper scrap; lead scrap; and spelter.

HEAT 54.

The furnace lining had been thoroughly scraped at the end of the previous day's run. The temperature was 1,020° F. (550° C.) at 5.30 a. m. The furnace was preheated from 6 to 6.30, using 84 kilowatt hours, before charging.

The charge was 400 pounds wet sawdust (384 pounds on dry basis) 400 pounds of rod ends, 248 pounds of copper scrap, 160 pounds of zinc, and 12.5 pounds of lead; total, 1,204.5 pounds. This composition allows 1⅝ per cent zinc for loss, the same as is allowed for melting with coke fires, over the desired alloy of 61 per cent copper, 36½ per cent zinc, and 2.5 per cent lead.

At 6.48 a. m. the sawdust was charged on the bottom, then the rod ends, and then the copper. The arc was turned on at 7.08; "safe rocking" was begun at 7.55. The charge had all melted at 8.17, after 154 kilowatt-hours had been used. The melt was speltered and the lead added at 8.33, after 179 kilowatt-hours had been used. "Full rocking" was started at 8.40. Pouring was begun at 8.53, and finished at 9.01. The power consumption was 194 kilowatt-hours, plus 5 for the motor driving the rocking device, or 199 in all. The temperature was 1,940° F. (1,060° C.). There was recovered 1,147 pounds of billet; hence the loss was 4.7 per cent on the dry basis. The furnace was not scraped. Some zinc was lost in speltering with the door open. No trouble of any sort was encountered. The arc was on 1 hour and 16 minutes, the total time elapsed being 2 hours and 13 minutes. The poured metal analyzed: Copper, 62.01 per cent; lead, 2.70 per cent; zinc (by difference), 35.29 per cent, or 2.8 per cent loss by analysis.

HEAT 55.

The charge was similar and was charged in the same manner as in heat 54. Charging was started at 9.04 a. m.; the arc was turned on at 9.14. At 9.37, after 60 kilowatt-hours had been used, one electrode stuck tight and broke off when an attempt was made to pull it out. Zinc and zinc oxide had condensed in the clearance between the electrode and the electrode hole, and as the chilling effect of the cold charge extended along the electrode through the lining, the molten zinc, that had condensed there during speltering on the previous heat, froze and soldered the electrode tightly in place. Barring out the broken electrode, scraping out the zinc and zinc oxide, and replacing the electrode caused 36 minutes delay; during this time the charge, which had begun to melt on top, froze into a practically solid mass, very hard to melt. "Safe rocking" was started at 10.26, after 100 kilowatt-hours had been used, including power required for the motor. "Full rocking" was begun at 10.52, after 160 kilowatt-hours had been used. At 10.58 the charge was speltered and the lead added. The arc was turned on again at 11.03 and was turned off at 11.08, when 188 kilowatt-hours had been used. The temperature was 1,975° F. (1,080° C.). Pouring was delayed on account of waiting for the crane, so from 11.16 to 11.24, 9 kilowatt-hours was used, including power for the motor, or 197 in all. The furnace was poured at 11.48 to 11.51, and was not drained; 1,096 pounds of ingot and 16 pounds of spillings were recovered, the apparent loss on the dry basis being 8.9 per cent. The metal analyzed: Copper, 62.75 per cent; lead, 2.65 per cent; zinc (by difference), 34.60 per cent, or 3.5 per cent loss by analysis.

HEAT 56.

In heat 56 the charge was 800 pounds of "sawdust" (768 on dry basis) 252 of copper, 165 of zinc, 18 of lead, total 1,203 pounds, calculated for 2.75 per cent excess zinc content, as would be used in coke-fired furnaces working on such a charge. Charging was started at 11.54, the "sawdust" being charged first, then the copper. The arc was turned on at 12.05 p. m. At 12.24, after 47 kilowatt-hours had been used, the operator intended to start "safe rocking," but had neglected to change the control from "full rocking." Both electrodes were broken, causing a delay of 55 minutes, and the charge had stuck together into a rather solid mass that was hard to melt. At 1.33, when 75 kilowatt-hours had been used, "safe rocking" was started. At 2.21, power consumption 165 kilowatt-hours, there was some solid copper and much molten metal; at 2.34, 175 kilowatt-hours used, "full rocking" was started, Some of the copper was still solid and fell on one electrode, breaking it. A delay of 29 minutes for replacing the electrode resulted, the furnace being open most of the time. At 3.12 "full rocking" was resumed; at 3.14, when 202 kilowatt-hours had been used, the charge was speltered and the lead added. As the operator had to wait for the crane, the arc was left off until 3.30, then it was run until 3.37. The furnace was poured at 3.45 to 3.57. The temperature was about 1,975° F. (1,080° C.). Much greenish dross, high in metallic content, was scraped out. The arc was on 1 hour and 32 minutes; the total time was 4 hours and 3 minutes. There were poured 1,141 pounds of ingot and 20 pounds representing spill, sample for analysis, and skull. The metal analyzed: Copper, 63.95 per cent; lead, 2.74 per cent; zinc (by difference), 32.31 per cent, or a 6 per cent loss by analysis.

HEAT 57.

The furnace had cooled over Saturday and Sunday. The long electrode cooler was removed from one electrode and was replaced with a copper coil. Monday morning 300 kilowatt-hours was put in. At 5.30 a. m. on Tuesday, the temperature was 700° F. (370° C.). From 6 to 6.33 the furnace was preheated with 102 kilowatt-hours. At 6.38 charging was started. The charge comprised 800 pounds of sawdust (768 on dry basis) 252 of copper, 200 of zinc (4½ per cent excess), and 18 of lead; total, 1,238 pounds. Half of the sawdust was placed on the bottom, then all the copper was added. At 6.47 the arc was turned on; at 7.15 after 75 kilowatt-hours had been used, "safe rocking" was started; at 7.33, 130 kilowatt-hours used, the rest of the borings were charged. At 7.56, 150 kilowatt-hours used, "safe rocking" was begun. At 8.31, 220 kilowatt-hours used, the charge was speltered and the lead added. At 8.40 the arc was turned on again, and full rocking was resumed. At 8.44 the temperature was 1,825° F. (1,000° C.), and the arc was shut off, as the caster said it was hot enough. Pouring was begun five minutes later, and was finished at 8.53. The dross was scraped out. The arc was on 1 hour and 24 minutes; the total time elapsed was 2 hours and 15 minutes. There was no trouble from electrodes sticking in this heat. The furnace had used 230 kilowatt-hours, and the motor 4, total 234. There was poured 1,155 pounds of metal, showing a loss of 5.9 per cent. The metal analyzed: Copper, 61.35 per cent; lead, 2.74 per cent; zinc (by difference), 35.91 per cent, or 5 per cent loss by analysis.

HEAT 58.

In heat 58 an attempt was made to melt sawdust with the use of less zinc than was required by the previous charges. The charge comprised 1,200 pounds of sawdust (1,152 on dry basis) 20 of zinc, 18 of lead, and 8 of spillings from heat 57; total, 1,208 pounds; it was calculated for 3 per cent excess zinc content. Charging was started at 8.58 a. m., with about half of the sawdust in. The arc was turned on at 9.05 a. m. At 9.13 the electrode with the coil cooler stuck fast. The electrode was not moved but the coil was pulled back so the electrode would heat up, and the arc was adjusted with the other electrode. At 9.30, when 65 kilowatt-hours had been used, "safe rocking" was started. At 9.34, the other electrode, the one with the long cooler, stuck fast and was broken in an attempt to free it. The broken piece was rammed out and replaced. The other electrode had loosened. More borings were charged; this was unwise as the charge froze solid. At 10.41, after 130 kilowatt-hours had been used, the balance of the borings was charged. "Safe rocking" was begun at 11.02. The metal was still solid at 11.33, but all of it was molten at 11.48, after 220 kilowatt-hours had been used. Then the melt was speltered through the spout.

The rocking motion was changed from "safe" to "full" rocking at 11.55. At 12 the arc was shut off; the furnace had taken 233 kilowatt-hours and the motor 4, total 237. The temperature was not taken, but the caster said it was hot enough. At 12.12 the operator finished pouring and scraped out much dross, high in metallic content. The time was as follows: Total time elapsed, 3 hours 14 minutes; arc on, 1 hour 33 minutes; delay, 42 minutes; charging, pouring, and looking to see state of metal, 59 minutes. There was poured 1,030 pounds, showing 14.7 per cent loss on dry basis, or 18 per cent on wet basis. The metal analyzed: Copper, 64.20 per cent; lead, 2.94 per cent; zinc (by difference), 32.86 per cent, or 8.1 per cent loss by analysis.

HEAT 59.

The metallic material of the charge comprised 750 pounds of wet borings (720 on dry basis), 25 of rod ends, 18 of zinc, and 9 of lead; total, 772 pounds on the dry basis; it was calculated for a 3 per cent excess zinc content. At the start the 750 pounds of wet borings and 5 pounds of soda ash as flux were charged. The flux was added on account of the formation of much dross in the preceding heats. At 12.12 the arc was turned on, and at 1.06 "safe rocking" was started, after 46 kilowatt-hours had been used. From 1.14 to 1.20 (6 minutes) the arc was off, and a fresh grip was taken on one of the electrodes, as they had worn enough to require this. At 1.34, 84 kilowatt-hours used, the rest of the charge, comprising 25 pounds of rod ends, 18 pounds of zinc, and 9 pounds of lead, was added through the spout. As the plant water supply had temporarily failed, there was no water for electrode cooling. An attempt was made to pour the metal but it was too cold. The arc was turned on again at 1.56 and at 2.09, when 114 kilowatt-hours had been used, "full rocking" was begun. The charge was poured at 2.24, after 144 kilowatt-hours had been used on the arc and 3 on the motor, total 147. There was poured 688 pounds of ingot. The total quantity of metal poured was 691 pounds, showing 11 per cent loss on the dry basis, or 14.2 per cent on the wet basis. The metal analyzed: Copper, 64.50 per cent; lead, 2.70 per cent; zinc (by difference), 32.80 per cent, or 6.7 per cent loss by analysis. At the end of the heat the electrodes were red outside the furnace through lack of water cooling. The electrode with the spiral-coil cooler was loose and the other was stuck.

GENERAL RESULTS OF THE SIX HEATS.

A summary of the results of the heats of extrusion metal is given in the table following:

Summary of results of heats 50 to 59.

Heat No.	Sawdust.		Water in saw-dust.	Rod ends.	Copper.	Zinc.	Lead.	Clean metal poured.	Dross.
	Wet basis.	Dry basis.							
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
54	400	384	16	400	248	160	12½	1,147	[a] 111
55	400	384	16	400	248	160	12½	1,112	
56	800	768	32	....	252	165	18	1,161	
57	800	768	32	....	252	200	18	1,165	
58	1,200	1,152	48	[b] 8	....	30	18	1,030	[a] 84
59	750	720	30	25	....	18	9	691	
Total	4,350	4,176	174	833	1,000	733	88	6,306	[c] 195
				2,654				90	
	7,004 (wet basis) 6,830 (dry basis)							6,396	

[a] Some of the dross was not recovered.
[b] From heat 57.
[c] Assay showed metallic content of 46 per cent, or 90 pounds.

The table shows that from a charge of 6,830 pounds of metallic material, with 114 pounds of water, or 7,004 pounds total weight, there was recovered 6,306 pounds of clean metal and 90 pounds of metal recoverable from dross, or 6,396 pounds in all. Thus the actual metal loss was 6,830 − 6,396 = 434 pounds, or 6.3 per cent, based on the metallic content of the charge. The gross loss, based on the weight of wet charge, 7,004 pounds, to clean metal, 6,306 pounds, is 698 pounds, or 9.9 per cent.

This loss seems very high. As no companion runs were made on these mixtures in the coke fires, the Detroit Copper & Brass Rolling Mills later ran a pot of wet borings alone in a coke fire and got 18 per cent gross loss. This result may be compared with those of heats 58 and 59, where 1,950 pounds of wet borings and 127 pounds of other material was charged, and 1,721 pounds of clean metal was poured. Then, assuming no loss on the material other than borings, 1,721 − 127 = 1,594 pounds would have been poured. Hence, the gross loss on the borings would be 356 pounds, or 18.3 per cent.

For all six heats, no loss being assumed on the 2,654 pounds of material other than borings, 4,350 pounds of borings would have given 6,306 − 2,654 = 3,652 pounds, or a gross loss of 698 pounds, or 15 per cent.

That is, the gross losses, although large, are about the same as in the coke fires, and seem to be due to the presence of the cutting compound. The water in the borings was 2 to 6 gallons per heat.

The representatives of the Detroit Copper & Brass Rolling Mills stated that the metal losses on its material were not excessive, considering the nature of the material, ands aid that the furnace would be promising for use on such an alloy if the mechanical difficulties were overcome.

Inasmuch as electrode troubles interfered with heats 55, 56, and 58, requiring the furnace to be opened and the arc to be left off for considerable periods, higher losses would be expected on these heats. The 100-pound capacity laboratory furnace melted 30 per cent zinc ingot, manganese-bronze borings, and German-silver scrap without trouble and with lower losses than those in fuel-fired furnace practice. Little speltering was done in the laboratory furnace, heat L24 being the only one in which much spelter was used. The original notes on the laboratory experiments were burned in the fire at Cornell University that destroyed the office used by the Bureau of Mines. The reports prepared on these experiments do not mention any trouble from the electrodes sticking. It is recalled that in one run, probably heat L25, the electrodes did show signs of sticking, but no trouble was experienced which prevented satisfactory operation of the small furnace, or seemed to call for special comment.

The electrodes were not water-cooled and probably ran hotter than those in the larger furnace after water-cooling was used.

As is shown by results of tests designated by reference Nos. 28, 29, 33, in Table 2 (p. 39), the larger furnace melted yellow scrap, no spelter being added, of 21, 24, and 30 per cent zinc content without difficulty and with lower losses than the coke-fired furnaces.

The difficulties in heats 54 to 59 seemed to be caused entirely by the sticking of the electrodes through deposition of the zinc vapor that was evolved when large amounts of spelter were being added to the hot charge. Less trouble was encountered in melting 30 per cent zinc scrap in the electric furnace than in melting a 20 per cent zinc brass (also without speltering) in the Rennerfelt furnace, from personal observation of the Rennerfelt and from reports received on its operation. The Scoville Manufacturing Co. reports that trouble was encountered in the electrodes sticking in their experiments on melting yellow brass in a Stassano-type furnace.

In the rocking furnace no trouble was met from electrodes sticking when melting alloys with a high lead content, even as much as 26 per cent lead, although with the Rennerfelt furnaces at Chicago, in melting alloys containing less than 15 per cent lead, so much trouble was caused from the electrodes sticking, and as a result, breaking, that large openings were made about the electrodes and no attempt was made to keep the furnaces tight. On alloys ranging up to 30 per cent zinc content, made from previously alloyed material, there was no trouble, provided rocking was started early enough in the heat, the power input was not allowed to go too high, the charge was held down to not more than 1,200 pounds, or, better still, to 1,000 pounds, and the metal was not allowed to get much hotter than the proper pouring temperature. If any of these precautions, neglect of which tends to the production of excessive zinc vapor in the furnace, was overlooked, there was a slight tendency for the electrodes to stick. This sticking could always be overcome by cutting down the flow of electrode cooling water and thus allowing the electrodes to run hotter and keep the condensed zinc molten.

When any condensation has taken place, it is wise to remove the electrodes at the end of the day and scrape out the holes with a 4-inch reamer while they are still hot. Otherwise, freezing of the condensed zinc might cause the electrodes to be stuck the next morning. On 24-hour operation this would not be required.

Hence the furnace worked satisfactorily on charges high in volatile metals, except when much metallic zinc was added to a hot, molten charge.

It would be desirable to attempt reversing the usual order of charging, putting the zinc into the hot furnace first, and then the scrap brass and copper, in the hope that the melted zinc would take up enough brass and copper to raise its vapor pressure before the temperature rises to the boiling point of zinc. This is understood to be the regular practice in the electric-furnace work of the Scoville Manufacturing Co.

For satisfactory operation of the furnace on alloys requiring the addition of much spelter, an electrode packing or stuffing box that would keep the electrode gas-tight but still free to move would have to be devised.

The Michigan Smelting & Refining Co. made no yellow brass with the use of large amounts of spelter at the time of the first test, hence to test the making of such alloys in the large rocking furnace was impracticable. Also the Bureau of Mines laboratory equipment was needed for other and more pressing work, and time for such tests was lacking.

Hence, it seemed best to continue the test of the rocking furnace on the types of alloys made by the company, and postpone to a later time the study of its application to alloys requiring the addition of much spelter. Pending results of such work the rocking furnace as designed and operated had to be rated as not successful in handling this 36½ per cent zinc alloy when 160 or more pounds of spelter was added as such.

However, tests made in 1918, both on the laboratory furnace and on the furnace at Detroit, showed that the troubles met in runs 54 to 59 could be eliminated.

TESTS ON YELLOW BRASS IN LABORATORY FURNACE USING SPELTER.

After the first series of tests of the large rocking furnace at Detroit was completed, a further series of tests was made with the laboratory furnace to study the sticking of the electrodes when spelter is added. The laboratory furnace had been entirely dismantled to make room for other furnaces, and brick of the size previously used in the lining were not at hand, so the hearth was made 12 inches in diameter by 12 inches long, which reduced the capacity of the furnace. The roof part of the lining was of "corundite" circle brick, the rest was ordinary fire brick. Spiral coils of copper tubing were used outside the furnace for electrode cooling, in order to make conditions more nearly like those in the large furnace.

The electrodes were first introduced through holes that were lined with alundum cement and closely fitted the electrodes, leaving as small a clearance as would permit the electrodes to move readily. Heats L53 to L57 were made on various manganese alloys, these being for another investigation.

TESTS WITH ELECTRODES PASSING THROUGH REFRACTORY WALLS.

SPELTERING LAST.

HEAT L58.

This was a wash heat, to clean the furnace and saturate the lining with copper. Four large copper ingots weighing 90.7 pounds were charged into the cold furnace. The arc was turned on, and after heating 40 minutes, when 25 kilowatt-hours had been used, rocking was begun at the "safe rocking" angle and was gradually increased to "full rocking." After 1 hour and 18 minutes, total time, the furnace was at 1,250° C. and was poured. The total power consumption was 35 kilowatt-hours. As a result, 89.5 pounds of metal was recovered, showing a loss of 1.2 pounds (1.35 per cent) from metal soaking into the hearth or being retained in the furnace. A little charcoal was used in this and in all subsequent heats.

HEAT L59.

Sixty pounds of copper ingot was charged into the hot furnace. Rocking was started after 15 minutes, when 12.25 kilowatt-hours had been used. The arc was run for 20 minutes, total time. The power consumption was 14.25 kilowatt-hours and the temperature was 1,300° C. The melt was cooled 10 minutes with the door open (after adding charcoal) to 1,175° C., then speltered with 32 pounds of zinc. Then rocking was resumed, the arc run 1 minute, using 0.75 kilowatt-hour, total 15 kilowatt-hours, and the furnace was poured at 1,075° C. There was obtained 89.9 pounds of metal, showing a loss of 2.1 pounds (2.33 per cent).

HEAT L60.

Thirty pounds of copper ingot and 45.1 pounds of brass from heat L59 were charged into the hot furnace. After 14 minutes heating, when 8 kilowatt-hours had been used, rocking was begun, and after 22 minutes, 11 kilowatt-hours used, the temperature was 1,200° C, and the metal was jumping. At this time 3.4 pounds of brass ingot was added, then 16.5 pounds of zinc. Then the furnace was started rocking again, and the arc was run for 1 minute longer, when 0.25 kilowatt-hour, or a total of 11.25 kilowatt-hours, had been used and the temperature was 1,075° C. The amount of metal recovered on pouring was 95.2 pounds, indicating an apparent gain of 0.2 pound.

The electrodes did not stick during these three heats. After this run the holes and the electrodes were not cleaned, but were left undisturbed overnight, no effort being made to work them loose. In the morning they were rather tight, but could be moved without difficulty. Some zinc oxide and a few tiny globules of metallic zinc adhered to the electrodes, there being more on the one used for adjusting the arc. This electrode is moved oftener and hence tends to enlarge the hole faster than the other electrode does.

SPELTERING FIRST.

HEAT L61.

To preheat the furnace before making brass, 90 pounds of copper ingot was charged into the cold furnace. The arc was turned on, and the furnace rocked as usual; time, 55 minutes; power consumption, 35 kilowatt-hours; pouring temperature, 1,290° C. There was obtained 90.5 pounds of ingot, showing 0.5 pound gain. The excess was evidently from brass clinging to the lining after heat L60.

HEAT L62.

Twelve minutes after the arc was stopped on heat L61, charging was started; 21.6 pounds zinc, in six pieces, 29.6 pounds of brass from heat L59, in three ingots, and 40 pounds of copper electrotypes, soldering-iron heads, and heavy wire was charged. The zinc was placed on the bottom, the brass above that, and the copper next the arc. Nine minutes after charging was started the arc was turned on. The furnace was rocked through a small arc from the very start of the heat. In six minutes a few slight puffs of zinc smoke escaped about the electrodes; smoke escaped at intervals up to 17 minutes, by which time the rocking angle had been increased to "full rock," when the furnace was perfectly tight. Thirty minutes after the arc had been started it was stopped, 12¼ kilowatt-hours having been used. When the door was opened clouds of zinc smoke were emitted. The temperature was 1,120° C. and the metal was jumping violently. In all, 89.7 pounds of metal was poured; a few drops of zinc oozed out at the adjusting electrode.

HEAT L63.

In this run 21.7 pounds of zinc, in seven pieces; 31 pounds of ingot from heat L60, in three ingots; 21.4 pounds of copper, in four ingots; and 19 pounds of copper scrap were charged. The zinc was placed at the bottom, and the copper at the top, as before. The arc was started 15 minutes after it was off on heat L62. Rocking through a small angle was begun at once, and the angle was gradually increased. Slight fumes were emitted about the electrodes after about 10 minutes, but these soon ceased and the furnace ran absolutely tight. No further oozing out of zinc was noted. After the arc had run 30 minutes, using 11.75 kilowatt-hours, the metal was poured at 1,065° C. Including buttons taken from the furnace the next morning, 92.9 pounds of metal was obtained.

At the end of this heat both electrodes were perfectly free, although metallic zinc could be seen about the adjusting electrode at a couple of points. Next morning both electrodes were tight. The nonadjusting electrode could be moved without using much force, but a pipe wrench had to be used to take out the adjusting electrode. There were only a few tiny globules of zinc on the nonadjusting electrode, but more on the adjusting one, and all the irregularities and depressions in the hole in the refractory end wall were filled with zinc. There was very little oxide coating on either electrode.

The scheme of charging the spelter at the start worked well. The condensation of zinc in heat L62 was probably due to overheating at the end, the metal being too hot. Also, probably from the overheating, the electrodes were stuck tighter the next morning than they were after heats L59 and L60, yet there was no sign that any great excess pressure of zinc vapor was created through charging spelter at the start. There was no further metal loss.

The method of charging the zinc first has the following advantages. Metal loss in speltering is avoided, heat is saved by not having to open the furnace for speltering, time is saved, and elimination of the fume of speltering decreases the likelihood of the furnace tender getting brass "shakes." Seemingly the method should not cause any more electrode trouble than is caused by speltering last, and it should certainly be used where possible.

TESTS WITH ELECTRODES PARTLY INCLOSED IN GRAPHITE SLEEVES.

In order to try the effect of a graphite sleeve about the electrode, sleeves of Acheson graphite were made. These were about 3 inches in outside diameter, 2 inches in inside diameter, and 4 inches long, and gave just enough clearance to slip readily over the electrodes. On one end (No. 1) a sleeve was inserted 2 inches into the refractory lining, so that the electrode passed through 7 inches of alundum lining inside the furnace, and then through 4 inches of graphite sleeve, 2 inches of which extended outside the furnace. On the other end (No. 2) the wall was so cut away that the electrode passed through 4 inches of alundum lining on the inside, then through the 4 inches of graphite sleeve.

HEAT L64.

After the furnace had been preheated empty for 17 minutes, using 10 kilowatt-hours, 83.3 pounds of brass ingot from heat L63, and 0.8 pound zinc were charged. The arc was run 34 minutes, using 18.5 kilowatt-hours. Rocking was begun 13 minutes after the arc started, when 7 kilowatt-hours had been used. The metal was poured at 1,050° C., 80.9 pounds of ingot being obtained. No fumes escaped about the electrodes.

HEAT L65.

Into the hot furnace was charged 21.1 pounds zinc, then 30 pounds brass ingots from run L60, then 40 pounds of copper (about 30 pounds in 10-pound ingot, balance scrap). Rocking was begun early in the heat. The arc was run 28 minutes, using 12.5 kilowatt-hours, and the metal poured at 1,060° C. No fumes escaped. The amount of metal recovered was 90.9 pounds.

The No. 2 electrode was stuck at the start of heat L65 and the arc was regulated by adjusting electrode No. 1.

HEAT L66.

The furnace was allowed to cool 2½ hours between heat L65 and heat L66, and both electrodes were stuck. They were forced out, and drops of zinc were found in the clearance between the refractory walls and the electrodes, but none between the graphite sleeves and the electrodes. Electrode No. 1, with the longer refractory wall, was soldered more tightly than No. 2. The holes and the electrodes were cleaned and the latter replaced. Into the warm furnace, without further preheating, was charged 21.3 pounds of zinc, then 30.5 pounds of brass ingot from run L65, then 40 pounds copper (¾ ingot, ¼ scrap). The arc was run 32 minutes, using 17½ kilowatt-hours. Rocking was begun early in the heat. The metal was poured at 1,070° C., 90 pounds being obtained. No leakage of zinc vapor occurred. Throughout this heat the electrodes were loose and moved freely.

The next morning both electrodes were stuck tight. As before, there was condensed zinc between the electrode and the refractory, but none between the electrode and the sleeve.

TESTS WITH ELECTRODES IN GRAPHITE SLEEVE AND IN GRANULAR CARBON PACKING.

The last three runs indicated that the graphite sleeve should extend entirely through the end wall and that the electrode should not bear against the refractory wall. Hence, one side of the furnace was provided with two 4-inch sleeves placed end to end, giving an 8-inch bearing of electrode against the graphite sleeve, and no bearing against the refractory wall. On the other end, an alundum ring about 1 inch thick was left on the inner wall of the furnace, and a pocket 4 inches in diameter was cut in the wall, giving a 1-inch opening all around the electrode. The alundum ring gave an appreciable clearance between the electrode and the refractory lining, but was too small to let the packing, 10-mesh granular carbon, fall through into the furnace. The granular packing was held in place by a 1-inch graphite slab fastened against the outside of the end wall, the electrode passing through a 2-inch hole in the slab. A hole for inserting the packing was cut in the slab. After the electrode had been inserted, carbon packing was poured in and tamped down, until the packing completely filled the annular space, then the hole was closed with a graphite plug.

HEAT L67.

After the empty furnace was preheated, with a power consumption of 13 kilowatt-hours, 92.3 pounds of ingot brass—11.25 pounds from heat L59, 33.65 from heat L60, 47.40 from heat L62—was charged. Rocking was begun after 10 minutes. After 36 minutes, 17.25 kilowatt-hours being used, the metal was at 1,070° C.; 91.1 pounds was poured. After 25 minutes a little fume came out around the electrode with the granular packing, but none escaped around the one with the graphite sleeve.

Both electrodes were loose throughout the heat. The one with granular packing showed a slight tendency to bind, evidently due to packing of the granular carbon, but did not stick.

HEAT L68.

Into the hot furnace were charged 20.8 pounds zinc, 30.3 pounds ingot brass from heat L62, and 40 pounds of zinc (15 ingot, 25 scrap). The arc was on 22 minutes, and 13.75 kilowatt-hours was used. Rocking was started after 10 minutes. The metal was poured at 1,070° C.; 90.4 pounds was obtained. Both electrodes ran perfectly gas tight, without fuming, and were loose throughout the run.

The furnace was allowed to cool three hours. The electrodes were then a little tighter than at the end of the heat, but could both be moved without difficulty. After the first loosening, the electrode with the sleeve moved easier than the one with granular packing. The latter seemed to be slightly bound, apparently from jamming of the carbon granules and not from deposition of zinc.

HEAT L69.

In this heat, 20.6 pounds of zinc, 10.5 pounds of brass ingot from heat L64, 17.5 pounds of copper ingot, and 22.5 pounds of copper scrap were charged into the warm furnace, without preheating. The furnace was heated 42 minutes, 18.75 kilowatt-hours being used. Rocking was begun early in the heat. The metal was poured at 1,075° C.; 91.1 pounds was obtained.

HEAT L70.

In heat L70, 21.4 pounds of zinc, 30.9 pounds of brass ingot from heat L64, and 41 pounds of copper (half ingot, half scrap) were charged into the hot furnace. The arc was run 32 minutes, using 12.75 kilowatt-hours. Rocking started early in the heat. The metal was poured at 1,075° C.; 91.9 pounds was obtained.

HEAT L71.

The furnace was hot. Eleven pounds of zinc, 16.9 pounds of ingot brass from run L64, 38.5 pounds of ingot brass from run L66, and 20.2 pounds copper (half ingot, half scrap) were charged. The arc ran 32 minutes, using 13 kilowatt-hours. Rocking started early in the heat. The metal was poured at 1,080° C., 87.1 pounds being obtained.

GENERAL RESULTS OF HEATS L67 TO L71.

The electrodes did not stick during any of the five heats (Nos. L67 to L71), and were free the next morning. No zinc or zinc oxide was found on either electrode, on the graphite sleeve, or on the granular carbon packing. No fume escaped at the electrodes.

The electrode with the granular packing was very rough in spots from chipping off the zinc oxide accretion that formed when the electrode was run in contact with the refractory wall and without packing. This roughness probably accounts for the slight binding of that electrode when used with the granular packing. Either the graphite sleeve or the granular packing bids fair to eliminate sticking troubles. Of course, tests on the large-size furnace extending over a long period of time will be required to solve the problem fully. As far as can be told from the behavior of the laboratory furnace, it seems almost a certainty that no serious difficulty will be met in avoiding the sticking of electrodes by leading the electrode through either a graphite sleeve or a packing of granular graphite, coke, carborundum, or similar material.

The metal losses are shown in the table following:

Metal losses in 14 heats with the laboratory rocking furnace.

Heat No.	Charge.				Metal, poured, pounds.	Loss, pounds.	Apparent gain, pounds.	Loss, per cent.	Apparent gain, per cent.
	Brass, pounds.	Copper, pounds.	Zinc, pounds.	Total, pounds.					
L58	....	90.7	....	90.7	89.5	1.2	....	1.35	....
L59	....	60.0	32.0	92.0	89.9	2.1	....	2.33	....
L60	48.5	30.0	16.5	95.0	95.2	....	0.2	....	0.21
L61	....	90.0	....	90.0	90.5	....	0.5	....	0.55
L62	29.6	40.0	21.6	91.2	89.7	1.5	....	1.64	....
L63	31.0	40.4	21.7	93.1	92.9	0.2	....	0.22	....
L64	83.3	....	....	83.3	80.9	2.4	....	2.78	....
L65	30.0	40.0	21.1	91.1	90.9	0.2	....	0.22	....
L66	30.5	40.0	21.3	91.8	90.0	1.8	....	1.96	....
L67	92.3	....	....	92.3	91.1	1.2	....	1.30	....
L68	30.3	40.0	20.8	91.1	90.4	0.7	....	0.77	....
L69	31.7	40.0	20.6	92.3	91.1	1.2	....	1.30	....
L70	30.9	41.0	21.4	92.3	91.9	0.4	....	0.43	....
L71	55.4	20.2	11.0	86.6	87.1	....	0.5	....	0.57
Total				1,272.8	1,261.1	....	....	....	....
Less 180.7 pounds copper (L58, L61)				180.7	180.7	....	....	....	....
				1,092.1	1,080.4	11.5	....	1.06	....

Thus, the loss in melting 493.5 pounds of ingot 2:1 brass, 391.6 pounds of copper, and 208 pounds of zinc, or 45 per cent of previously alloyed material and 55 per cent of new metal, was less than 1.1 per cent.

The metal loss determined by weight may be due to mechanical loss of the alloy—that is, of both zinc and copper—or to volatilization of zinc during pouring, or to both. The analysis of the various lots of brass made are given below:

Results of analyses of brass.

Heat No.	No.	Composition as calculated on basis of no loss.		Actual composition.		Per cent less zinc in metal poured than in calculated charge.
		Copper content.	Zinc content.	Copper (by analysis).	Zinc (by difference).	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	
L59	1	65.3	34.7	65.7	34.3	0.4
L60	2	65.3	34.7	65.4	34.6	.1
L62	3	65.2	34.8	65.7	34.3	.5
L63	4	65.3	34.7	65.7	34.3	.4
L64	5	66.1	33.9	66.5	33.5	.4
L65	6	65.3	34.7	65.2	34.8	[a].1
L66	7	65.2	34.7	65.6	34.4	.3
L67	8	65.6	34.4	66.5	33.5	.9
L68	9	66.0	34.0	66.2	33.8	.2
L69	10	66.3	33.7	66.1	33.9	[a].2
L70	11	66.6	33.4	66.8	33.2	.2
L71	12	65.5	34.5	65.5	34.5	.0

[a] Apparent gain.

The slight apparent gains in zinc content shown in the results of heats L65 and L69 may be due to the presence of nonmetallic materials in the scrap copper. The highest loss was on a heat (No. L67) where all previously alloyed ingot was remelted. The average loss by analysis, 0.4 per cent, means that a weighed out charge of 65 pounds of copper and 35 pounds of zinc yielded 65 pounds of copper and 34.3 pounds of zinc, or a calculated loss by weight of about 0.71 per cent, due to volatilization of zinc. The total loss, then, in this series of tests was about 0.4 per cent mechanical loss and 0.7 per cent volatilization loss.

POWER CONSUMPTION.

So far it has been shown that the large rocking furnace worked well, both, mechanically and metallurgically, on any alloy tried, as long as speltering was not involved, and tests in the laboratory furnace indicate that slight changes in the method of leading in the electrodes will make speltering possible, that lining, electrode, and labor costs are reasonable, and that metal losses are reduced. The remaining main factor is the power consumption.

The watt-hour meter was installed on the secondary side of the transformer at the furnace switchboard. Hence the transformer losses and lead losses are not shown by this meter. In order to determine the magnitude of these losses a portable meter was put on the primary side, and the following readings of the power used for the arc were made by the Detroit-Edison meter department.

Comparison of power readings on primary and secondary circuits.

Heat No.	Secondary.	Primary.	Ratio (secondary: primary).
	Kw.-hours.	*Kw.-hours.*	
206	173	173	100:100
207	165	180	100:109
208	178	211	100:118
Total	516	564	a 100:109

a Average.

These determinations do not agree well, probably because the portable meter on the primary circuit is not readable to the same degree of accuracy as the one on the secondary. The average ratio shows that the power loss in the transformers and leads is about 10 per cent, which is rather higher than normal for such installations.

Mr. E. L. Crosby, of the Detroit Edison Co., says:

> I would state the power factor and kilowatt-hour consumption in terms of the secondary readings, as that is the character of this load. The additional reactance and current losses of high-tension transformation should be looked upon exactly as they are in any other power business, as being incidental to securing a wholesale rate which would more than compensate for the increased investment in high-tension equipment and the losses involved. Power in the quantities involved by a 1,000 to 3,000 pound brass furnace might very well be sold at either primary or secondary rates, being dependent entirely on load factor. However, if two or more furnaces were used, the operation would be considerably cheaper at the primary rate.

That is, in Detroit one may either buy power at 4,600 volts, supplying his own transformer and paying for power metered on the high-tension side of the transformer, at a lower rate but for the total power consumed, or he may buy power at 130 volts, the power company furnishing the transformer, the power being metered on the low-tension side, and the consumer paying a higher rate for the lesser amount of power shown by the meter. Hence, in the results presented herein, the power figures will be given in terms of both secondary metering and primary metering, the latter being taken as 1.09 times the former.

Inasmuch as the true metallic content of the charges used, less the content of oil and dirt, is not accurately known, the power consumption has been figured on the gross charge. As small ingot, spillings, and metal poured into the "niggerhead," etc., were fed back into the furnace, usually without being weighed, during a run of several heats of the same composition, the actual amount of metal charged was often more than is given in the following pages.

The best basis for calculation is the power consumption, by primary metering, per unit of metal poured.

The power consumption will, of course, vary with the size of the charge and with the rate at which the furnace is used. If the furnace is run only a couple of heats a day, the power per ton of output will be much higher than if it is run 10 hours a day. If the furnace is run 24 hours a day, the power consumption per ton will be materially lower than on 10-hour operation.

Bulky charges, requiring a long time to charge, cut down the active running time, so that the power consumption will be higher on bulky charges than on compact charges, such as all ingot. Delays in pouring, such as waiting for the crane, also cut down power efficiency. The temperature to which the metal is heated greatly affects power consumption. If the furnace is run only a few hours a day, or only a few days a week, as in much of this test, the efficiency will be low compared with that on steady operation. That the large rocking furnace was not run on a steady basis was due to various factors. Often certain variables would be studied, and slight changes in the furnace or equipment made. Sometimes lack of material for melting would hold up both the coke-fired furnaces and the electric furnace. Again, in showing the Michigan Smelting and Refining Co. operator how to handle the furnace, no attempt was made at output. Throughout most of the test, experimental rather than regular operating conditions prevailed.

The power consumption is shown in Tables 6 and 7, in which are included all the days' runs that anywhere near approximated normal running for production. The periods of time given include any delays due to the furnace itself, and, unless noted under "Remarks," also include many incidental delays in waiting for the crane and ladle.

The power figures include any preheating of the empty furnace.

The averages represent what the furnace, as built, and working under the handicap of continual delays for crane and ladle, can do on the bulky, oily material used in the tests, week in and week out. Less oily or more compact charges, which would be met in the average foundry, would enable the furnace to give a larger output and a lower power consumption.

For alloys requiring higher pouring temperatures than those of the test, the output will be lower (assuming the same sort of charge as regards oiliness and bulkiness), but the power consumption will be higher; for alloys requiring lower pouring temperatures the reverse will apply.

TABLE 6.—*Data on*

CHARGE 622 POUNDS,

Date.	Heat No.	Alloy.				Character of charge.	Weight of charge.	Elapsed time, including charging, pouring, and all delays.	Power consumption, secondary.		
		Cu.	Sn.	Pb.	Zn.				Arc.	Motor.	Total secondary.
							Pounds.	*H. m.*	*Kw.-hrs.*	*Kw.-hrs.*	*Kw.-hrs.*
June 19........	12	76	8	13	3	Compact.....	655	2 12	198	4	202
Do.........	13	76	8	13	3	.....do........	655	1 35	148	3	151
Do.........	14	76	8	13	3	.....do........	655	1 06	99	2	101
Do.........	15	76	8	13	3	.....do........	655	1 10	105	2	107
Do.........	16	76	8	13	3	.....do........	655	1 17	115	2	117
Do.........	17	76	8	13	3	.....do........	655	1 12	103	2	105
Do.........	18	76	8	13	3	.....do........	655	1 03	93	2	95
Day total, 7 heats.	......	......	......	......	......	....	4,585	9 35	861	17	878
Aug. 3.........	116	67	1	2	30	Very bulky and oily.	600	1 30	133	2	135
Do.........	117	67	1	2	30	.....do........	600	1 00	100	2	102
Do.........	118	67	1	2	30	.....do........	600	1 20	87	2	89
Do.........	119	67	1	2	30	.....do........	600	1 25	101	2	103
Do.........	120	67	1	2	30	.....do........	600	1 10	132	2	134
Day total, 5 heats.	......	......	......	......	......	....	3,000	6 25	553	10	563
Aug. 4.........	121	67	1	2	30	Very bulky and oily.	600	1 15	133	2	135
Do.........	122	67	1	2	30	.....do........	600	1 30	100	2	102
Do.........	123	67	1	2	30	.....do........	600	1 05	90	2	92
Do.........	124	67	1	2	30	.....do........	600	1 15	83	2	85
Do.........	125	67	1	2	30	.....do........	600	1 10	85	1	86
Do.........	126	67	1	2	30	.....do........	600	1 15	102	2	104
Do.........	127	67	1	2	30	.....do........	600	1 00	93	2	95
Day total, 7 heats.	......	......	......	......	......	....	4,200	8 30	686	13	699
Oct. 26.........	167	68	1	7	24	Rather bulky	628	1 20	125	3	128
Do.........	168	68	1	7	24	.....do........	628	1 30	136	3	139
Do.........	169	68	1	7	24	.....do........	628	1 20	114	2	118
Do.........	170	68	1	7	24	.....do........	628	1 15	96	1	97
Do.........	171	68	1	7	24	.....do........	628	1 25	97	2	99
Do.........	172	68	1	7	24	.....do........	628	1 10	100	1	101
Do.........	173	68	1	7	24	.....do........	628	1 10	118	2	120
Day total, 7 heats.	......	......	......	......	......	....	4,396	9 10	786	14	802
4 day's total, 26 heats.	......	......	......	......	......	....	16,181	33 40	2,886	54	2,942
Average...	......	......	......	......	......	....	622	{a1 13 {b8 25	......	......	......

[a] Average time per heat.

[b] Average day.

power consumption.

APPROXIMATELY.

Pouring temperature.		Weight poured.	Power consumption, primary.	Secondary power consumption per 100 pounds of metal—		Primary power consumption per 100 pounds of metal—		Remarks.
°F.	°C.			Charged.	Poured.	Charged.	Poured.	
		Pounds.	*Kw.-hrs.*					
2,030	1,110	....	....	31	....	....	....	Furnace not normally hot at start.
2,300	1,260	....	....	23	....	....	....	
2,170	1,185	....	....	15.5	....	....	....	
2,220	1,215	....	....	16.5	....	....	....	
2,100	1,150	....	....	18	....	....	....	Not including 40 minutes at noon hour.
2,220	1,215	....	....	16	....	....	....	
2,160	1,185	....	....	14.5	....	....	....	
2,160	1,185	4,449	956	19.2	19.8	21.0	21.5	
....	....	....	....	22.5	....	....	....	Furnace not quite normally hot at start.
....	....	....	....	17	....	....	....	
....	....	....	....	15	....	....	....	Metal a little cold.
....	....	....	....	17	....	....	....	
....	....	....	....	22	....	....	....	Nearly 200 pounds of spill, drip, etc., charged in run 120, beside regular 600-pound charge.
1,970	1,075	2,811	614	18.8	20	20.5	22	
....	....	....	....	22.5	....	....	....	
....	....	....	....	17	....	....	....	
....	....	....	....	15.5	....	....	....	
....	....	....	....	14	....	....	....	
....	....	....	....	14	....	....	....	
....	....	....	....	17.5	....	....	....	Waited 20 minutes for ladle.
....	....	....	....	16	....	....	....	
1,970	1,075	3,771	763	16.5	18.5	18.2	20.2	
....	....	....	....	20.5	....	....	....	Furnace normal at start.
....	....	....	....	22	....	....	....	Ladle cold, much skull added to next heat.
....	....	....	....	19	....	....	....	
....	....	....	....	15.5	....	....	....	
....	....	....	....	15.5	....	....	....	
....	....	....	....	16	....	....	....	
....	....	....	....	19	....	....	....	75 pounds of spill, etc., extra, charged with this heat.
2,010	1,100	4.075	872	18.3	19.7	19.9	21.4	
2,020	1,105	15,106	3,205	18.3	19.5	20.0	21.3	
....	....	....	....	[c] 366	[c] 390	[c] 400	[c] 426	

[c] Per ton of material charged.

TABLE 6.—*Data on power*

CHARGE 1,300 POUNDS,

Date.	Heat No.	Alloy.				Character of charge.	Weight of charge.	Elapsed time, including charging, pouring, and all delays.	Power consumption secondary.		
		Cu.	Sn.	Pb.	Zn.				Arc.	Motor.	Total secondary.
							Pounds	*H. m.*	*Kw.-hrs.*	*Kw.-hrs.*	*Kw.-hrs.*
June 22........	20	76	8	13	3	Compact.....	1,312	2 30	300	4	304
Do..........	21	76	8	13	3	.....do.......	1,312	1 55	194	4	198
Do..........	22	76	8	13	3	.....do.......	1,312	1 55	180	4	184
Do..........	23	76	8	13	3	.....do.......	1,312	1 30	175	3	178
Do..........	24	76	8	13	3	.....do.......	1,312	2 00	173	3	176
Day's total, 5 heats.	......	......	......	......	......	....	6,560	9 50	1,022	18	1,040
July 5..........	28	85	5	5	5	.....do.......	1,318	2 30	286	3	289
Do..........	29	85	5	5	5	.....do.......	1,295	2 00	197	1	198
Do..........	30	85	5	5	5	.....do.......	1,155	1 40	153	1	154
Do..........	31	85	5	5	5	.....do.......	1,288	1 30	169	1	170
Do..........	32	85	5	5	5	.....do.......	1,338	2 00	150	1	151
Day's total, 5 heats.	......	......	......	......	......	....	6,394	9 40	955	7	962
July 17..........	47	84	7	8	1	All borings...	1,315	2 55	355	3	358
Do..........	48	84	7	8	1	.....do.......	1,310	2 55	253	3	256
Do..........	49	84	7	8	1	.....do.......	1,965	3 00	332	6	338
Day's total, 3 heats.	......	......	......	......	......	....	4,590	8 50	940	12	952
July 18..........	50	84	7	8	1	.....do.......	1,384	2 40	350	4	354
Do..........	51	84	7	8	1	.....do.......	1,200	1 45	228	3	231
Do..........	52	84	7	8	1	.....do.......	1,300	2 10	192	3	195
Do..........	53	84	7	8	1	.....do.......	1,300	2 00	178	2	180
Day's total, 4 heats.	......	......	......	......	......	....	5,184	8 35	948	12	960
Sept. 6..........	83	73	4	20	3	Compact.....	1,310	2 40	276	5	281
Do..........	84	73	4	20	3	.....do.......	1,310	2 05	201	4	205
Do..........	85	73	4	20	3	.....do.......	1,306	1 55	197	5	202
Do..........	86	73	4	20	3	.....do.......	1,306	2 00	191	3	194
Day's total, 4 heats.	......	......	......	......	......	....	5,432	8 40	865	17	8824
Sept. 7..........	87	72½	6½	17½	3½	.....do.......	1,306	2 35	262	5	267
Do..........	88	72½	6½	17½	3½	.....do.......	1,306	2 05	225	4	229
Do..........	89	72½	6½	17½	3½	.....do.......	1,308	2 05	187	5	192
Do..........	90	72½	6½	17½	3½	.....do.......	1,308	1 50	161	4	165
Do..........	91	72½	6½	17½	3½	.....do.......	1,308	1 20	153	2	155
Day's total, 5 heats.	......	......	......	......	......	....	6,536	9 55	988	20	1,008
Sept. 11........	94	76	8	13	3	.....do.......	1,306	2 50	284	6	290
Do..........	95	76	8	13	3	.....do.......	1,306	2 40	205	4	209
Do..........	96	76	8	13	3	.....do.......	1,306	2 10	185	5	190
Do..........	97	76	8	13	3	.....do.......	1,306	2 00	187	3	190
Do..........	98	76	8	13	3	.....do.......	1,306	1 40	191	3	194
Day's total, 5 heats.	......	......	......	......	......	....	6,530	11 20	1,052	21	1,073

consumption—Continued.

APPROXIMATELY.

Pouring temperature.		Weight poured.	Power consumption, primary.	Secondary power consumption per 100 pounds of metal—		Primary power consumption per 100 pounds of metal—		Remarks.
°F.	°C.			Charged.	Poured.	Charged.	Poured.	
		Pounds.	*Kw.-hrs.*					
2,150	1,175	....	....	23	....	....	....	Furnace colder than normal at start.
2,150	1,175	....	....	15	....	....	....	
2,130	1,165	....	....	14	....	....	....	
2,160	1,180	....	....	13.5	....	....	....	Time includes 35 minutes at noon.
2,100	1,150	....	....	13.5	....	....	....	
2,140	1,170	6,347	1,134	15.8	16.4	17.3	17.9	
1,950	1,070	....	....	22	....	....	....	Furnace colder than normal at start.
2,010	1,100	....	....	15.5	....	....	....	
1,950	1,065	....	....	13.5	....	....	....	
2,200	1,205	....	....	13.5	....	....	....	
1,875	1,025	....	....	11.5	....	....	....	
2,000	1,095	6,210	1,050	15.0	15.5	16.5	16.9	
2,100	1,150	....	....	27	....	....	....	Furnace cool at start. Heat 47 includes 50 minutes (82 kw.-hours used) preheating.
2,125	1,160	....	....	19.5	....	....	....	
2,150	1,175	....	....	17.3	....	....	....	
2,125	1,160	4,416	1,039	20.7	21.5	22.6	23.5	
2,250	1,235	....	....	25.5	....	....	....	
2,200	1,205	....	....	19	....	....	....	
2,225	1,220	....	....	15	....	....	....	
2,100	1,150	....	....	14	....	....	....	
2,190	1,200	5,070	1,048	18.5	19.0	20.2	20.7	
....	....	....	....	21.5	....	....	....	Furnace colder than normal at start. Heat 83 includes 20 minutes (35 kw.-hours used) preheating.
....	....	....	....	15.5	....	....	....	
....	....	....	....	15.5	....	....	....	
....	....	....	....	14.5	....	....	....	
2,100	1,150	5,119	961	16.3	17.3	17.7	18.8	
....	....	....	....	20.5	....	....	....	
....	....	....	....	17.5	....	....	....	
....	....	....	....	14.5	....	....	....	
....	....	....	....	12.5	....	....	....	
....	....	....	....	12	....	....	....	
2,125	1,160	6,410	1,099	15.5	15.7	16.9	17.2	
....	....	....	....	22	....	....	....	Time excludes 30 minutes' wait for crane.
....	....	....	....	16	....	....	....	
....	....	....	....	14.5	....	....	....	
....	....	....	....	14.5	....	....	....	
....	....	....	....	14.5	....	....	....	Excludes 30 minutes' wait for crane.
2,125	1,160	6,478	1,182	16.5	16.6	18.1	18.3	

TABLE 6.—*Data on powr-*

CHARGE 1,300 POUNDS, AP

Date.	Heat No.	Alloy.				Character of charge.	Weight of charge.	Elapsed time, including charging, pouring, and all delays.	Power consumption secondary.		
		Cu.	Sn.	Pb.	Zn.				Arc.	Motor.	Total secondary.
							Pounds.	*H. m.*	*Kw.-hrs.*	*Kw.-hrs.*	*Kw.-hrs.*
Sept. 12	99	72½	6½	17½	3½	Average	1,306	2 45	227	5	232
Do	100	72½	6½	17½	3½	do	1,306	2 00	211	5	216
Do	101	72½	6½	17½	3½	do	1,306	1 55	204	4	208
Do	102	72½	6½	17½	3½	do	1,306	1 35	193	4	197
Do	103	72½	6½	17½	3½	do	1,306	2 00	187	4	191
Day's total, 5 heats.							6,530	10 15	1,022	22	1,044
Sept. 13	104	72½	6½	17½	3½	Average	1,306	2 30	233	6	239
Do	105	72½	6½	17½	3½	do	1,306	2 15	207	3	210
Do	106	72½	6½	17½	3½	do	1,306	1 40	188	4	192
Do	107	72½	6½	17½	3½	do	1,306	1 15	178	3	181
Do	108	72½	6½	17½	3½	do	1,306	1 10	170	2	172
Day's total, 5 heats.							6,530	8 50	976	18	994
Oct. 10	132	84	4	4	8	Bulky	1,310	3 00	313	4	317
Do	133	84	4	4	8	do	1,310	2 00	216	4	220
Do	134	84	4	4	8	do	1,310	1 45	190	2	192
Do	135	84	4	4	8	do	1,310	1 55	181	3	184
Do	136	84	4	4	8	do	1,310	1 30	179	3	182
Day's total, 5 heats.							6,550	10 10	1,079	16	1,095
Oct. 11	137	84	4	4	8	Bulky	1,306	2 45	298	4	302
Do	138	84	4	4	8	do	1,306	1 50	201	2	203
Do	139	84	4	4	8	do	1,306	1 45	180	4	184
Do	140	84	4	4	8	do	1,306	1 50	178	3	181
Do	141	84	4	4	8	do	1,306	1 50	195	4	199
Day's total, 5 heats.							6,530	10 00	1,052	17	1,069
Oct. 18	153	78	2	10	10	Average	1,308	2 30	280	4	284
Do	154	78	2	10	10	do	1,308	2 00	216	3	219
Do	155	78	2	10	10	do	1,308	1 20	218	4	222
Day's total, 3 heats.							3,924	5 50	714	11	725
Oct. 25	163	84	6	10	0	Bulky	1,306	2 20	277	4	281
Do	164	84	6	10	0	do	1,306	2 15	218	4	222
Do	165	84	6	10	0	do	1,306	1 40	196	3	199
Do	166	84	6	10	0	do	1,306	1 35	199	3	202
Day's total, 4 heats.							5,224	7 50	890	14	904
Oct. 29	174	79	9	10	2	Average	1,310	3 25	378	4	382
Do	175	79	9	10	2	do	1,310	2 00	230	3	233
Do	176	79	9	10	2	do	1,310	2 00	214	4	218
Do	177	79	9	10	2	do	1,310	1 35	195	3	198
Day's total, 4 heats.							5,240	9 00	1,017	14	1,031

consumption—Continued.

PROXIMATELY—Continued.

Pouring temperature.		Weight poured.	Power consumption, primary.	Secondary power consumption per 100 pounds of metal—		Primary power consumption per 100 pounds of metal—		Remarks.
°F.	°C.			Charged.	Poured.	Charged.	Poured.	
		Pounds.	*Kw.-hrs.*					
......	......	......	......	18	......	......	......	Time excludes 10 minutes' wait for ladle.
......	......	......	......	16.5	......	......	......	Time excludes 15 minutes' wait for ladle.
......	......	......	......	16	......	......	......	Do.
......	......	......	......	15	......	......	......	Do.
......	......	......	......	14.5	......	......	......	
2,125	1,160	6,315	1,139	16.0	16.5	17.5	18.0	
......	......	......	......	18.5	......	......	......	
......	......	......	......	16	......	......	......	
......	......	......	......	14.5	......	......	......	
......	......	......	......	14	......	......	......	
......	......	......	......	13	......	......	......	
2,100	1,150	6,333	1,084	15.4	15.7	16.7	17.2	Furnace not fully hot at start.
......	......	......	......	24	......	......	......	Heat 132 includes 50 minutes (75 kw.-hours used) preheating.
......	......	......	......	17	......	......	......	
......	......	......	......	14.5	......	......	......	
......	......	......	......	14	......	......	......	
......	......	......	......	14	......	......	......	
2,050	1,125	6,147	1,191	16.8	17.8	18.2	19.3	
......	......	......	......	23	......	......	......	Heat 137 includes 40 minutes (70 kw.-hours used) preheating.
......	......	......	......	15.5	......	......	......	
......	......	......	......	14	......	......	......	
......	......	......	......	14	......	......	......	
......	......	......	......	15	......	......	......	About 100 pounds of spill added to this heat.
2,100	1,150	6,361	1,160	16.3	16.7	17.8	18.2	
......	......	......	......	22	......	......	......	Furnace much cooler than usual at start.
......	......	......	......	17	......	......	......	
......	......	......	......	17	......	......	......	
2,100	1,150	3,766	791	18.4	19.4	20.2	21.0	
......	......	......	......	21½	......	......	......	
......	......	......	......	17	......	......	......	1½ hours' delay between heats 163 and 164, waiting for charge.
......	......	......	......	15	......	......	......	
......	......	......	......	15.5	......	......	......	
2,190	1,200	4,902	984	17.3	18.4	19.0	20.2	
......	......	......	......	29	......	......	......	Furnace almost cold at start; was not run the prior two days.
......	......	......	......	18	......	......	......	Heat 174 includes 1 hour 25 minutes (100 kw.-hours used) preheat. Excludes 15 minutes delay for crane.
......	......	......	......	16.5	......	......	......	
......	......	......	......	15	......	......	......	
2,100	1,150	5,166	1,128	20.1	20.4	21.5	22.2	

TABLE 6.—*Data on power*

CHARGE 1,300 POUNDS, AP

Date.	Heat No.	Alloy.				Character of charge.	Weight of charge.	Elapsed time, including charging, pouring, and all delays.		Power consumption, secondary.		
		Cu.	Sn.	Pb.	Zn.					Arc.	Motor.	Total secondary.
							Pounds.	*H.*	*m.*	*Kw.-hrs.*	*Kw.-hrs.*	*Kw.-hrs.*
Oct. 30	178	79	9	10	2	Bulky	1,310	2	40	259	4	263
Do	179	79	9	10	2	do	1,310	2	05	230	4	234
Do	180	79	9	10	2	do	1,310	1	35	210	3	213
Do	181	79	9	10	2	do	1,310	1	50	189	3	192
Do	182	79	9	10	2	do	1,310	1	50	196	4	200
Day's total, 5 heats.	......	......	......	......	......	......	6,550	10	00	1,084	18	1,102
Oct. 31	183	67½	4	26½	2	Bulky	1,310	2	30	313	3	316
Do	184	67½	4	26½	2	do	1,310	2	05	218	3	221
Do	185	67½	4	26½	2	do	1,310	11	55	200	3	203
Do	186	67½	4	26½	2	do	1,310	1	50	189	3	192
Do	187	67½	4	26½	2	Compact	700	11	10	110	2	112
Day's total, 5 heats.	......	......	......	......	......	......	5,940	9	30	1,030	14	1,044
Nov. 1	......	......	......	......	......	......	......	2	00	151	......	151
Nov. 2	188	84	6	10	0	Average	1,304	2	55	299	5	304
Do	189	84	6	10	0	do	1,308	2	15	252	4	256
Do	190	85	5	5	5	Compact	1,892	2	10	260	4	264
Do	191	71¼	1¾	5	21	Bulky	1,314	1	50	183	4	187
Day's total, 4 heats.	......	......	......	......	......	......	5,818	9	10	994	17	1,011
Including Nov. 1, preheat.	......	......	......	......	......	......	......	11	10	1,045	17	1,162
Nov. 5	192	85	5	9	1	Average	1,314	3	40	257	4	261
Do	193	85	5	9	1	do	1,314	1	50	219	3	222
Do	194	79	9	10	2	Little bulkier than average.	1,304	1	35	196	2	198
Do	195	79	9	10	2		1,304	1	30	190	2	192
Do	196	79	9	10	2		1,304	1	40	190	3	193
Day's total, 5 heats.	......	......	......	......	......	......	6,540	10	15	1,052	14	1,066
Nov. 6	197	79	9	10	2	Little bulkier than average.	1,304	1	45	235	3	238
Do	198	79	9	10	2		1,304	1	30	199	3	202
Do	199	79	9	10	2		1,304	1	40	186	2	188
Do	200	79	9	10	2		1,304	1	40	176	2	178
Do	201	79	9	10	2		1,304	1	30	162	2	164
Do	202	79	9	10	2		1,304	1	45	160	2	162
Day's total, 6 heats.	......	......	......	......	......	......	7,824	9	50	1,118	14	1,132

consumption—Continued.

PROXIMATELY—Continued.

Pouring temperature.		Weight poured.	Power consumption, primary.	Secondary power consumption per 100 pounds of metal—		Primary power consumption per 100 pounds of metal—		Remarks.
°F.	°C.			Charged.	Poured.	Charged.	Poured.	
		Pounds.	*Kw.-hrs.*					
....	....	....	....	20	....	....	....	
....	....	....	....	18	....	....	....	
....	....	....	....	16.5	....	....	....	Excludes 15 minutes' wait for crane.
....	....	....	....	14.5	....	....	....	Do.
....	....	....	....	15	....	....	....	Includes 15 minutes (11 kw.-hours used) in draining furnace for change of alloy.
2,050	1,125	6,349	1,201	16.8	17.4	18.4	18.9	
....	....	....	....	24	....	....	....	Includes 30 minutes and (53 kw.-hours used) preheating.
....	....	....	....	17	....	....	....	
....	....	....	....	15.5	....	....	....	
....	....	....	....	14.5	....	....	....	
....	....	....	....	16	....	....	....	
2,150	1,175	5,850	1,138	17.6	17.9	19.2	19.5	
....	....	....	165	....	....	....	....	Foundry not running; empty furnace, heated.
....	....	....	....	23	....	....	....	Furnace cooler than usual at start.
....	....	....	....	19.5	....	....	....	
....	....	....	....	14	....	....	....	
....	....	....	....	14	....	....	....	
2,190	1,200	5,604	1,102	17.4	18.1	19.0	19.6	
....	....	....	1,267	20.0	20.7	21.8	22.6	
2,000	1,095	....	....	20	....	....	....	Furnace cooler than usual, not run previous 2 days. Heat 192 includes 1 hour and 20 minutes (100 kw.-hours used) preheating.
2,050	1,120	....	....	17	....	....	....	
2,125	1,165	....	....	15	....	....	....	
2,200	1,205	....	....	14.5	....	....	....	
2,200	1,205	....	....	15	....	....	....	Time includes 20 minutes for charging heat 197.
2,115	1,155	6,360	1,162	16.3	16.8	17.8	18.3	
2,125	1,165	....	....	18.5	....	....	....	
2,175	1,190	....	....	15.5	....	....	....	
2,250	1,230	....	....	14.5	....	....	....	
2,240	1,225	....	....	13.5	....	....	....	
2,100	1,150	....	....	12.5	....	....	....	
2,125	1,165	....	....	12.5	....	....	....	Time includes 20 minutes for charging heat 203.
2,185	1,195	7,571	1,236	14.7	15.0	15.8	16.3	

TABLE 6.—*Data on power*

CHARGE 1,300 POUNDS, AP

Date.	Heat No.	Alloy.				Character of charge.	Weight of charge.	Elapsed time, including charging, pouring, and all delays.	Power consumption, secondary.		
		Cu.	Sn.	Pb.	Zn.				Arc.	Motor.	Total secondary.
							Pounds.	*H. m.*	*Kw.-hrs.*	*Kw.-hrs.*	*Kw.-hrs.*
Nov. 7	203	79	9	10	2	Little bulkier than average.	1,304	1 35	215	3	218
Do	204	79	9	10	2		1,304	1 40	195	2	197
Do	205	79	9	10	2		1,304	1 30	180	2	182
Do	206	79	9	10	2		1,304	1 35	173	2	175
Do	207	84	6	10	0	Very bulky	1,304	1 40	165	2	167
Do	208	87½	5	½	7	do	1,304	2 30	178	3	181
Day's total, 6 heats.							7,824	10 30	1,106	14	1,120
Nov. 8	209	84	6	10	0	Very bulky	1,300	3 00	246	2	248
Do	210	84	6	10	0	do	1,300	1 40	198	3	201
Do	211	84	6	10	0	do	1,300	2 05	188	2	190
Do	212	84	6	10	0	do	1,300	1 30	169	3	172
Do	213	84	6	10	0	do	1,300	1 50	170	1	171
Day's total, 5 heats.							6,500	10 05	971	11	982
Nov. 9											
Do	214	84	6	10	0	Very bulky	1,300	1 45	223	4	227
Do	215	84	6	10	0	do	1,300	2 05	198	3	201
Do	216	84	6	10	0	do	1,300	1 50	195	2	197
Do	217	84	6	10	0	do	1,300	1 45	189	3	192
	218	84	6	10	0	do	1,300	1 25	165	2	167
Day's total, 5 heats.							6,500	8 50	970	14	984

consumption—Continued.

PROXIMATELY—Continued.

Pouring temperature.		Weight poured.	Power consumption, primary.	Secondary power consumption per 100 pounds of metal—		Primary power consumption per 100 pounds of metal—		Remarks.
°F.	°C.			Charged.	Poured.	Charged.	Poured.	
		Pounds.	*Kw.-hrs.*					
2,125	1,165			17				
2,165	1,185			15				
2,175	1,190			14				
2,140	1,170			13.5				
2,150	1,175			13				
1,950	1,065			14				Includes 50 minutes' delay from electrode breaking in charging bulky charge, also 20 minutes charging heat 209.
2,120	1,160	7,583	1,210	14.4	14.8	15.5	16.0	
2,050	1,120			19				Time includes 1 hour and 10 minutes' delay from electrode breaking, owing to bulky charge; long delay due to filing down oversize nipple.
2,175	1,190			15.5				
2,175	1,190			14.5				Includes 25 minutes for adjusting electrode holder.
2,175	1,190			13.5				
2,175	1,190			13				Includes 20 minutes for charging heat 214.
2,150	1,175	6,341	1,069	15.1	15.5	16.5	16.9	
2,175	1,190			17.5				
2,200	1,205			15.5				
2,160	1,180			15				
2,250	1,235			14.5				
2,150	1,175			13				
2,190	1,200	6,407	1,073	15.2	15.4	16.5	16.7	

TABLE 7.—*Summary of power consumption.*

Date.	Number heats.	Quantity of material charged.	Time elapsed.	Power consumption, secondary circuit.			Pouring temperature.	Weight poured.	Power consumption, primary circuit.
				Arc.	Motor.	Total secondary.			
		Pounds.	*Hrs.min.*	*Kw.-hrs.*	*Kw.-hrs.*	*Kw.-hrs.*	*°C.*	*Pounds.*	*Kw.-hrs.*
June 22	5	6,560	9.50	1,022	18	1,040	1,170	6,347	1,134
July 5	5	6,394	9.40	955	7	962	1,095	6,210	1,050
July 17	3	4,590	8.50	940	12	952	1,160	4,416	1,039
July 18	4	5,184	8.35	948	12	960	1,200	5,070	1,048
Sept. 6	4	5,432	8.40	865	17	882	1,150	5,119	961
Sept. 7	5	6,536	9.55	988	20	1,008	1,160	6,410	1,099
Sept. 11	5	6,536	11.20	1,052	21	1,073	1,160	6,478	1,182
Sept. 12	5	6,530	10.15	1,022	22	1,044	1,160	6,315	1,139
Sept. 13	5	6,530	8.50	976	18	994	1,150	6,333	1,084
Oct. 10	5	6,550	10.10	1,079	16	1,095	1,125	6,147	1,191
Oct. 11	5	6,530	10.00	1,052	17	1,069	1,150	6,361	1,160
Oct. 18	3	3,924	5.50	714	11	725	1,150	3,766	791
Oct. 25	4	5,224	7.50	890	13	903	1,200	4,902	984
Oct. 29	4	5,210	9.00	1,017	14	1,031	1,150	5,166	1,128
Oct 30	5	6,550	10.00	1,084	18	1,102	1,125	6,349	1,201
Oct. 31	5	5,940	9.30	1,030	14	1,044	1,175	5,850	1,138
Nov. 1 and 2	4	5,818	11.10	1,045	17	1,162	1,200	5,604	1,267
Nov. 5	5	6,540	10.15	1,052	14	1,066	1,155	6,360	1,162
Nov. 6	6	7,824	9.50	1,118	14	1,132	1,195	7,571	1,236
Nov. 7	6	7,824	10.30	1,106	14	1,120	1,160	7,583	1,210
Nov. 8	5	6,500	10.05	971	11	982	1,175	6,341	1,069
Nov. 9	5	6,500	8.50	970	14	984	1,200	6,407	1,073
Total 22 days	103	135,256	198.55	21,896	334	22,330	[a] 1,160	131,105	24,346
Last 5 days	27	35,188	41.30	5,217	67	5,284	[b] 1,175	34,262	5,750

[a] 2,125° F.

[b] 2,150° F.

NOTE.—In the last 5 days (November 5–9) the arc was on 32 hours, 17½ hours being spent in charging and pouring, that is, the average power demand while the arc was running was 163 kilowatts at 85 per cent average power factor on secondary side; average demand is 192 kilovolt amperes. Voltage averaged 131 on open circuit, 116 under load, that is, the average current on secondary side is 1,650 amperes. With an average power factor of 77 per cent on the primary side, the average demand on the primary is 211 kilovolt amperes, thus one 200 kilowatt (rated capacity) transformer is sufficient.

Average power consumption, entire 22 days and last 5 days.

	Entire 22 days.	Last 5 days of run.
Average charge, pounds	1,313	1,304
Average time for days run, hours and minutes	9 . 03	9 . 54
Average time per heat, hours and minutes	1 . 56	1 . 50
Total gross metal loss including oil and dirt:		
Pounds	4,151	926
Average per cent	3.07	2.65
Average output, pounds of metal poured per hour	657	692
Average power consumption per 100 pounds of material charged, kw.-hours:		
Secondary circuit	16.50	15.05
Primary circuit	17.90	16.35
Average power consumption per 100 pounds of metal poured, kw.-hours:		
Secondary circuit	17.0	15.4
Primary circuit	18.5	16.8
Average power consumption per ton of material charged, kw.-hours:		
Secondary circuit	330	301
Primary circuit	358	327
Average power consumption per ton of metal poured, kw.-hours:		
Secondary circuit	340	308
Primary circuit	370	336

EFFECT OF SIZE OF CHARGES.

On 622-pound charges heated to 1,105° C., average, the power consumption measured on the primary side, was 400 kilowatt-hours per ton of material charged, but this figure is high because it is based on an 8½-hour day. On 1,304-pound charges, heated to 1,160° C. the average power consumption was 358 kilowatt-hours per ton for the period represented by the last 22 days and 327 for that represented by the last five days.

As only two heats, Nos. 49 and 190, were made on 1,950-pound charges, there are not enough data to tell the power consumption on large heats. There should be a slight improvement over the figures for 1,300-pound charges on increasing the charge to 1,500 pounds, which the furnace is capable of handling readily.

It should be noted that the rocking type of furnace promises to show good efficiency, not only in the larger sizes but in the smaller ones as well.

In the last series of tests, the laboratory furnace when lined in such a way as to have only about 90-pound capacity, gave the following results on yellow brass, pouring temperature 1,075° C.

Results in melting 2:1 yellow brass, poured at 1,075° C, in laboratory furnace.

Heat.	Charge, pounds.	Power consumption, measured on secondary.		Pouring temperature, ° C.	Condition of furnace.
		Total kilowatt-hours.	Kilowatt-hours per 100 pounds.		
L67	92.3	30.25	33	1,070	Cold.
L68	91.1	13.75	15	1,070	Hot.
L69	92.3	18.75	20	1,075	Cool after cooling 3 hours.
L70	92.3	12.75	14	1,075	Hot.
L71	86.6	13	15	1,080	Do.
Total or average.	454.6	88.5	19.5 [a] 395		

[a] Average kilowatt-hours per ton.

When lined for about 125-pound capacity, the furnace gave the following results on red brass, poured at 1,200° C.

Results in melting red brass, poured at 1,200° C, in laboratory furnace.

Heat.	Charge, pounds.	Power consumption, measured on secondary.		Pouring temperature, ° C.	Condition of furnace.
		Total kilowatt-hours.	Kilowatt-hours per 100 pounds.		
L34	127.3	39	31	1,140	Cold.
L35	127.7	30.5	25	1,180	Hot.
L36	128.5	26.5	20	1,220	Do.
L37	126.5	22.5	18	1,220	Do.
L38	129.5	19	15	1,200	Do.
Total or average.	639.5	137.5	21.5 [a] 430	....	

It would seem that a rocking furnace of, say, 500-pound capacity might be useful for foundries whose output is too small to permit the economical use of one of larger size.

CALCULATED EFFECT OF 24-HOUR OPERATION.

As in 24-hour operation the furnace would always be fully hot, the power consumption on that basis would be not higher, and would probably be less, than the figures for the last two heats of the day when running on a 10-hour schedule.

This is seen to be, for melting red brass in a furnace of 1,500-pound capacity, about 330 (primary) kilowatt-hours per ton poured for 625-pound charges and 290 for 1,310-pound charges, or on the best figures, would be 275 per ton for the latter charge.

FURTHER TESTS MADE IN 1918.

After the conclusion, in November, 1917, of the tests conducted by the Bureau of Mines at Detroit, the furnace lay idle till the beginning of April, 1918. Although a member of the Michigan Smelting & Refining Co.'s staff had been trained in handling the furnace, no observations were made and no data were recorded by that firm on the operation of the furnace during the 1917 test, as no member of the technical staff could be spared from his other work.

In March, 1918, Mr. C. T. Bragg, who had become works manager of the Michigan Smelting & Refining Co., decided to make additional tests of the furnace, with a view to the installation of other furnaces of this type if the test proved satisfactory.

As 24-hour operation was to be tried and a few runs made on speltered extrusion metal, the Bureau of Mines took the opportunity of obtaining additional data on these points, which had not been thoroughly covered by the previous test, and sent a representative to Detroit to cooperate in the test.

The metal-loss records for heats 219 to 221, made with 220 volts, when the arc was uncontrollable, had shown that as a result of the excessive power drawn by the arc at that voltage the roof had failed and permitted molten metal to penetrate the lining. However, the lining seemed to be in fair shape, and the company decided to try a few heats without relining. The metal losses continued slightly higher than normal, even with an all-ingot charge, and finally, in heat 230, the roof failed visibly.

The roof part and the end walls were relined. Only the inner corundite lining required replacement, as the heat-insulating bricks were in good condition; 207 pounds of metal was removed from behind the brick. The original lining of the hearth proper seemed good for indefinite service and was left in. Close-fitting graphite sleeves were placed about the electrodes in the manner indicated in the description of the laboratory experiments. Sixty-two man-hours were required in repairing the lining.

The furnace was then run intermittently for a few days.

Table 8 shows the results obtained from running the furnace a few hours daily—that is, at much less than its capacity.

TABLE 8.—*Data on 1918 tests, 10-hour operation or less.*

[Melting alloy consisting of 75¼ per cent Cu, 7½ per cent Sn, 14¼ per cent Tb, and 3 per cent Zn.]

Date.	Consecutive heat No.	Day heat No.	Weight of charge.	Elapsed time.	Melting time.	Power used for arc and rocking motor.		Weight of ingots poured.	Power consumption (primary) per ton of metal poured.	Remarks.
						Secondary.	Equivalent primary.			
			Pounds.	*Hr. min.*	*Hr. min.*	*Kw.-hrs.*	*Kw.-hrs.*	*Pounds.*	*Kw.-hrs.*	
Apr. 22	235	1	1,300	3 45	2	373	...	...	...	Furnace practically cold at start. Time includes 1 hour 5 minutes for preheating; 100 kilowatt-hours put in.
Do	236	2	1,300	1 40	1 25	212	...	...	...	Pot of metal from coke fire spilled near switchboard, damaging meters and causing shutdown for balance of day.
Day's total	...	...	2,600	5 25	3 25	585	638	2,595	490	
Apr. 23	237	1	1,300	3 20	2 45	318	...	...	...	Furnace quite cold at start. Time includes 55 minutes for preheating; 75 kilowatt-hours used.
Do	238	2	1,300	1 55	1 20	202	...	...	...	
Do	239	3	1,300	1 47	1 8	175	...	...	...	
Do	240	4	1,300	1 42	1 6	164	...	...	...	
Do	241	5	1,300	1 34	1 4	159	...	...	...	
Day's total	...	...	6,500	10 18	7 23	1,018	1,112	6,337	352	
Apr. 24	242	1	1,300	2 12	1 40	233	...	...	...	
Do	243	2	1,300	2	1 32	194	...	...	...	
Do	244	3	1,300	1 50	1 18	175	...	...	...	
Do	245	4	1,300	1 30	57	157	...	...	...	
Do	246	5	1,300	1 40	1 4	153	...	...	...	Time includes 8 minutes' delay for changing broken electrode nipple.
Day's total	...	...	6,500	9 12	6 31	912	999	6,247	320	
Apr. 25	247	1	1,300	1 55	1 43	229	...	...	...	
Do	248	2	1,300	1 53	1 25	189	...	...	...	Faulty connection in small booster transformer; furnace was idle 4 hours between heats 248 and 249 for replacing transformer. Smaller transformer put in. Open-circuit voltage, 120 volts on heat 249 and thereafter.

Do	249	3	1,300	1	55	1	35	207				
Day's total			3,900	5	43	4	43	625	681	3,884	350	
Apr. 26	250	1	1,300	2	35	2	5	255				
Do	251	2	1,300	2	13	1	43	204				
Do	252	3	1,300	1	57	1	18	177				
Day's total			3,900	6	45	5	6	636	694	3,790	359	Furnace idle 1 hour 30 minutes between heats 250 and 251 for replacing broken electrode and altering cooling coil.
Apr. 27	253	1	1,300	2	27	2		225				Time includes 1 hour for preheating; 124 kilowatt-hours used.
Do	254	2	1,300	2	1	1	21	186				
Do	255	3	1,300	1	27	1	10	166				Saturday, foundry did not run during afternoon.
Day's total			3,900	5	55	4	31	577	630	3,846	328	
Apr. 29	256	1	1,305	3	40	2	13	357				Furnace cool from standing over Sunday. Time includes 1 hour 15 minutes for preheating; 100 kilowatt-hours put in.
Do	257	2	1,305	2	4	1	30	213				
Do	258	3	1,305	1	41	1	13	180				
Do	259	4	1,305	1	40	1	10	165				
Do	230	5	1,305	2	5	1	17	155				
Day's total			6,525	11	10	7	23	1,070	1,168	6,422	364	
Total			33,825	54	28	39	2	5,423	5,922	33,121	357	

Each charge in the heats given in Table 8 consists of 600 pounds of ingot, 200 of red borings (1 per cent oil), 50 of yellow fixtures, 344 of copper, and 106 of lead; total, 1,300 pounds.

The 33,825 pounds charged contained 52 pounds of oil, leaving 33,773 pounds of metallic material charged. From this, 33,121 pounds of good ingot was obtained; thus, the gross loss was 706 pounds, or 2.09 per cent, including oil. Nineteen pounds of scrap, which was not charged back, and 452 pounds of skimmings, containing 238 pounds of recoverable metallic material, was obtained, leaving a net metallic loss of 397 pounds, or 1.14 per cent. No account was taken of the recoverable metal in ladle skulls.

ACTUAL 24-HOUR OPERATION.

The results of a 4-day test in which the furnace was run approximately 24 hours daily are shown in Table 9. The power consumption was lower than had been calculated on the basis of the last heats of the day in 10-hour operation.

TABLE 9.—*Data for 1918 test, approximately 24-hour operation.*

Date.	Consecutive heat No.	Day heat No.	Weight of charge.	Composition of alloy.	Elapsed time.		Melting time.		Power used for arc and for rocking motor.		Power consumption (primary meter) per ton charged.	Remarks.
									Secondary.	Equivalent primary.		
			Pounds.		*H.*	*m.*	*H.*	*m.*	*Kw.-hrs.*	*Kw.-hrs.*	*Kw.-hrs.*	
April 30	261	1	1,305	Copper, 75¼; tin, 4½; lead, 14¼; and zinc, 3 per cent.	2	9	1	47	229			Furnace idle since 4.30 p. m. of Apr. 29. Charge for heat 261 put in furnace previous afternoon; heat started at 6.23 a. m.
Do	262	2	1,305	do	1	53	1	28	192			
Do	263	3	1,305	do	1	55	1	22	168			
Do	264	4	1,305	do	1	44	1	15	152			
Do	265	5	1,305	do	1	44	1	15	144			
Do	266	6	1,305	do	2	12	1	2	141			Time includes 30 minutes for adding electrode sections and taking fresh grips with holders.
Do	267	7	1,305	do	1	30		55	153			
Do	268	8	1,305	do	1	35		58	156			
Do	269	9	1,305	do	1	41	1	0	151			
Do	270	10	1,305	do	1	33	1	2	146			
May 1	271	11	1,305	do	1	33		59	143			
Do	272	12	1,305	do	1	47	1	6	149			
Do	273	13	1,305	do	2	1	1	2	150			
24 hours' total			16,965		23	17	15	11	2,074	2,260	*a* 266	
May 1	274	1	1,305	Copper, 75¼; tin, 4½; lead, 14¼; and zinc, 3 per cent.	2	11	1	18	143			Time includes 36 minutes' wait for helpers at pouring time
Do	275	2	1,305	do	1	49	1	12	147			
Do	276	3	1,305	do	1	40	1	7	152			
Do	277	4	1,305	do	1	35		55	147			
Do	278	5	1,305	do	1	45	1	12	142			
Do	279	6	1,305	do	3	..	1	20	160			Time includes 1 hour 10 minutes for replacing broken electrode and altering cooling coil
Do	280	7	1,305	do	1	22	1	2	151			
Do	281	8	1,305	do	1	21		57	146			
Do	282	9	1,305	do	1	19		53	145			
Do	283	10	1,305	do	1	23		55	151			
May 2	284	11	1,305	do	1	31		56	152			
Do	285	12	1,305	do	1	34	1	1	152			

TABLE 9.—*Data for 1918 test, approximately 24-hour operation*—Continued.

Date.	Consecutive heat No.	Day heat No.	Weight of charge.	Composition of alloy.	Elapsed time.		Melting time.		Power used for arc and for rocking motor.		Power consumption (primary meter) per ton charged.	Remarks.
									Secondary.	Equivalent primary.		
			Pounds.		*H.*	*m.*	*H.*	*m.*	*Kw.-hrs.*	*Kw.-hrs.*	*Kw.-hrs.*	
May 2	286	13	1,305	Copper, 75¼; tin, 4½; lead, 14¼; and zinc, 3 per cent.	1	20		48	141			
Do	287	14	1,305	do	1	35		53	147			
24 hours' total			18,270		23	35	14	29	2,076	2,262	*a* 248	
May 2	288	1	1,305	Copper, 75¼; tin, 4½; lead, 14¼; and zinc, 3 per cent.	1	35	1	5	150			Furnace idle 45 minutes between shifts.
Do	289	2	1,305	do	1	25		52	145			
Do	290	3	1,305	do	1	25		57	143			
Do	291	4	1,305	do	1	20		55	144			
Do	292	5	1,305	do	1	35	1	2	144			
Do	293	6	1,305	do	1	39		56	141			Long delay resulted in pouring this heat.
Do	294	7	1,300	Copper, 84; tin, 6; and lead, 10 per cent.	1	31	1	4	140			
Do	295	8	1,300	do	1	18		50	150			
Do	296	9	1,300	do	1	48		59	158			
Do	297	10	1,300	do	1	22		52	151			
Do	298	11	1,300	do	2	13	1	5	156			Time includes 39 minutes' delay for repairing broken electrode.
May 3	299	12	1,300	do	1	28		59	162			
Do	300	13	1,300	do	1	37	1	10	179			
Do	301	14	1,300	do	1	49	1	12	163			
24 hours' total			18,230		22	5	13	58	2,126	2,317	*a* 256	
May 3	302	1	1,300	Copper, 84; tin, 6; and lead, 10 per cent	1	43	1	14	167			Furnace idle 1 hour 20 minutes between shifts.
Do	303	2	1,300	do	1	43	1	22	158			Furnace idle 1 hour between heats 303 and 304.
Do	304	3	1,300	do	1	55	1	9	158			
Do	305	4	1,300	do	1	44	1	17	159			Furnace idle 25 minutes between heats 304 and 305 for patching electrode hole.
Do	306	5	1,300	do	1	50	1	16	166			
Do	307	6	1,300	do	1	35	1	10	162			

Do	308	7	1,300	do	1	23	1	10	162			
Do	309	8	1,300	do	2	15	1	5	165			Time includes 42 minutes for changing two electrodes broken in charging.
May 4	310	9	1,305	Copper, 75½; tin, 4½; lead, 14½; and zinc, 3 per cent.	1	19		55	152			
Do	311	10	1,305	do	1	14	1	0	140			
Do	312	11	1,305	do	1	21		50	142			
Do	313	12	1,305	do	1	36	1	13	144			End of heat, 6.35 a. m.
24 hours' total			15,620		19	38	13	41	1,875	2,044	a 262	
4 days' total, 53 heat			69,085		88	35	57	19	8,151	8,883	a 258	

a Average.

Total quantity of good ingot poured, 67,568 pounds; average power consumption (primary) per ton of good ingot poured, 264 kilowatt-hours; average output, 764 pounds per hour; output in heats 274 to 301, 815 pounds per hour; average elapsed time per heat, 1 hour 40 minutes; average melting time, 1 hour 5 minutes; average time for charging, pouring, and delays, 35 minutes; 20 minutes of this is delay not due to the furnace.

The charges for heats 256 to 293 and 310 to 313, with an alloy containing 75¼ per cent copper, 7½ per cent tin, 14¼ per cent lead, and 3 per cent zinc comprised 25,200 pounds of ingot; 11,220 of red borings (2 per cent oil); 1,400 of yellow borings (3 per cent oil); 1,540 of medium brass; 10,987 of cabbaged, tinned copper wire; 552 of ingot copper; and 3,906 of lead; total, 54,805 pounds.

The charges for heats 294 to 309, with an alloy containing 84 per cent copper, 6 per cent tin, and 10 per cent lead comprised 16,000 pounds of ingot, 4,704 of copper, and 96 of lead; total, 20,800 pounds.

METAL LOSSES IN THE 24-HOUR TESTS.

In heats 261 to 293 and 310 to 313, with the alloy containing 75¼ per cent copper, 7½ per cent tin, 14¼ per cent lead, and 3 per cent zinc, 48,305 pounds was charged, of which 305 pounds was oil, leaving 47,980 pounds of metallic material. From this 47,419 pounds of good ingot was poured, giving a gross loss of 886 pounds, or 1.83 per cent. Fifty-eight pounds of scrap metal was obtained and was not fed back, also 257 pounds of metallic material was obtained from 484 pounds of skimmings (assay by Michigan Smelting & Refining Co.'s chemist showed 53 per cent metallic material); hence, a total of 315 pounds of secondary metal was recovered.

Of the gross loss of 886 pounds, 305 pounds was oil and 315 was recovered as scrap or from skimmings, leaving 286 pounds of net metallic loss from 47,980 pounds metallic material charged; hence the net metal loss was 0.60 per cent.

In heats 294 to 309, with the 84 per cent copper, 6 per cent tin, 10 per cent lead alloy, 20,800 pounds was charged and 20,149 of good ingot was poured, giving a gross loss of 651 pounds, or 3.13 per cent. There were 43 pounds scrap not fed back, 130 pounds of recoverable metallic material in 246 pounds of skimmings, and 365 in 429 of ladle skulls; thus, the total recovery of secondary metal was 530 pounds, or 2.59 per cent, and the actual net loss was 113 pounds, or 0.54 per cent.

ELECTRODE CONSUMPTION.

The electrode consumption, including all waste from breakage, was less than 2 pounds per ton of metal melted in the four-day test of 24-hour operation.

FURTHER TESTS ON EXTRUSION METAL.

After the 24-hour tests were concluded, two heats were made with yellow borings alone and eight with extrusion metal containing 60 per cent copper, 37 per cent zinc, and 3 per cent lead, spelter being added in the latter, in order to study the sticking of the electrodes.

No attempt was made to get maximum production or minimum power consumption, nor to determine metal losses.

Before heat 235 was started close-fitting graphite sleeves had been placed about the electrodes. This arrangement was found to be helpful even in melting red brass, as the electrodes always worked smoothly in the sleeves and without friction, which had sometimes given trouble when the electrodes passed directly through the refractory wall.

The electrodes tended to stick slightly during the four preliminary heats, until experience had shown how hot the electrodes should be permitted to run. The zinc that condenses in the clearance space between the electrode and the sleeve should be kept molten by using no cooling water in the electrode cooling coils until the latter part of the first heat in the morning and none between heats when the arc is off for pouring and charging.

On May 7, 1918, a run (No. 318) was made with a 600-pound charge, comprising 100 pounds of billet ends, 340 of oily yellow borings (very light and bulky), 61 of copper, and 75 of zinc. The empty, nearly cold furnace was preheated with 92 kilowatt-hours; it then stood 3 hours, when all the material was charged, except the zinc, which was added at the end of the heat.

The furnace ran smoothly but took 155 kilowatt-hours for the arc, because of the previous three hours' cooling, and 4 for the motor.

In the next heat, No. 319, the charge was of the same weight and composition and was also speltered at the end of the run. In this heat 103 kilowatt-hours was used by the arc and 2 kilowatt-hours by the motor.

In heat 320 a 1,200-pound charge of the same composition was used and was speltered at the end, as in the two previous heats; 153 kilowatt-hours was used by the arc and 3 by the motor. After this heat the electrodes were removed and a few drops of zinc were found in the sleeves. No zinc oxide was found. The electrodes and sleeves were cleaned and the electrodes were replaced. The billets poured from this heat analyzed 60.46 per cent copper.

The charge for heat 321, which was to be run the next morning, consisted of 1,200 pounds of the same material as before. The 150 pounds of metallic zinc was charged in the bottom of the hot furnace and covered with the borings, on top of which were charged the billet ends and the copper. Then the door was replaced, and a vent left for the oil vapors and gas to escape, in which condition the furnace and charge was left over night. Next morning the arc was run two hours, using 224 kilowatt-hours; the rocking motor took 5 kilowatt-hours. The metal was very hot. The billets poured analyzed 59.84 per cent copper.

In heat 321, another 1,200-pound heat of the same composition as before, the zinc was charged first, then half of the borings, which were unusually bulky, was added. The furnace was rocked to aid in smoking off the oil, and the arc was run a few minutes, using 13 kilowatt-hours. The borings charged had shrunk enough that the rest of the borings could be added without being piled too thickly around the arc. The copper and billet ends were added last. After a total of 187 kilowatt-hours had been used by the arc and 4 by the motor, the charge was poured. The first ingot, poured from the first ladle before any billets were poured, was analyzed, also the last ingot from the heel of the second ladle, poured after all four billets had been poured, with the following results: First ingot, first ladle, 59.76 per cent copper; last ingot, second ladle, 59.54 per cent copper.

In heat 323, a 1,200-pound charge, of the same composition as before, was used. The borings were charged in two parts—the first part being heated a little before the second was added. Then the copper and the billet ends were charged. After 166 kilowatt-hours had been used, the zinc was added and 22 kilowatt-hours more was put in. The rocking motor used 4 kilowatt-hours.

The first and last ingots from this heat analyzed as follows:

First ingot, first ladle, 59.78 per cent copper; last ingot, second ladle, 59.66 per cent copper. These figures indicate the thorough mixing obtained by rocking.

The metal losses in these runs were not obtained, but the analysis shows that the calculated 60 per cent copper content was closely approached.

Speltering first worked just as well metallurgically as speltering last, and made working conditions pleasant for the attendants, as well as saving much time and preventing the loss of heat in removing the door and stopping to spelter.

By running the electrodes hot enough to keep the condensed zinc molten and, on 10-hour operation, by removing the electrodes and cleaning them and the sleeves of deposited zinc before the furnace cools enough for the zinc to solidify, the sticking of the electrodes should be entirely eliminated, as there was no sign of sticking on these last six runs.

No zinc smoke was emitted from the clearance between the electrode and the sleeve until the metal was within a few degrees of the proper pouring temperature for billets. The amount of zinc lost by volatilization about the electrodes was not enough to make an appreciable loss on a 1,200-pound charge.

Only 14 heats, in all, were made in the commercial size furnace on extrusion metal that required speltering.

As the Michigan Smelting & Refining Co. wished to use the furnace for regular production of red brass, the experiments with extrusion metal cartridge brass, or similar alloys high in zinc could not be continued long enough to show what the power consumption and output for such alloys would be under other than experimental conditions. However, as the melting points and the pouring temperatures of these alloys are lower than those of the red brasses, the power consumption attainable should be lower than the figures obtained in melting red brass.

Because of the relatively small amount of experimental work done with the furnace at Detroit on alloys requiring the addition of much spelter, no such definite statements can be made regarding the behavior of the furnace in melting these materials, as can be made regarding its performance with red brass, and alloys containing up to 30 per cent zinc, from scrap or other previously alloyed material.

However, the results of the experimental work so far indicate that after a few weeks development of the rocking electric furnace under rolling-mill conditions, it should melt alloys high in zinc as satisfactorily as the various other alloys so far melted in quantity in this furnace.

VITAL POINTS IN REDUCING POWER CONSUMPTION.

The main way to attain a low power cost is to cut down the idle time of the furnace as much as possible. If the furnace were run 24 hours on 1,350-pound charges heated to 1,160° C., charging in 10 minutes and pouring in 5 minutes, as is easily possible, a heat could be made in 1 hour 20 minutes, the arc being on 1 hour 5 minutes. Thus 18 heats or an output of 24,000 pounds per day could be made. The power consumption, metered on the primary circuit, would be about 250 kilowatt-hours per ton. This would be an output of about 1,000 pounds per hour or about 50 per cent more than that on 10-hour operation with ladle delays, thus decidedly cutting the interest charges on the investment.

Every effort should be made to keep the waste time in charging and pouring down to the minimum, and to hold the power input up while running. The heats should be made on the basis of power input, measured in kilowatt-hours, and not on a time schedule alone.

HEAT BALANCE.

In heats 197 to 208, two days, 20 hours' running time, 15,650 pounds of alloy, mostly 79 per cent Cu, 9 per cent Sn, 10 per cent Pb, 2 per cent Zn, was poured at an average temperature of 1,175° C. (2,150° F.). The power consumption, metered on the secondary, was 2,224 kilowatt-hours for the arc, and 28 for the motor; total, 2,252.

Richards [a] gives 7 kilowatt-hours per 100 pounds as the theoretical power needed to heat an alloy of 65 per cent Cu and 35 per cent Zn, or one of 85 per cent Cu and 15 per cent Sn to 10 per cent above their melting points (915° and 965° C.), or to only 1,006° and 1,056° C., respectively. These temperatures are not high enough for satisfactory pouring.

Hansen [b] gives 8.13 kilowatt-hours as the amount of power theoretically necessary for heating 100 pounds of 80 Cu, 20 Zn alloy to 1,100° C.

As a rough approximation one may take 8 kilowatt-hours per 100 pounds, or 160 per ton, as the theoretical value for the leaded bronze heated to 1,150–1,175° C. This figure is probably low rather than high.

As the ratio of the kilowatt-hour reading on the primary meter, when that was installed for test, to the kilowatt-hour reading on the secondary meter was 109:100, the power consumption becomes: Kilowatt-hours used on arc circuit, 2,446; on motor circuit, 28; total, 2,474, or 317 kilowatt-hours per ton. The heat balance on 10-hour operation is then about as follows:

Heat balance of rocking furnace working on 10-hour schedule.

	Kilowatt-hours.	Per cent.
Loss in transformers and leads	222	9
Power used by motor for rocking the furnace	28	1
Loss in cooling water:		
7.5 kw. per hour for 20 hours (2 days)	150	8
2 kw. (estimated) per hour for 28 hours (2 nights)	56	
Power usefully applied (theoretical), 15,650 pounds at 8 kilowatt-hours per 100 pounds melted	1, 252	51
Balance left for shell radiation losses, 48 hours, and door losses, while charging—12 charges	766	31
Total	2, 474	100

Of the 2,224 kilowatt-hours actually supplied to the furnace itself, 1,252 was usefully applied, giving a 56 per cent efficiency on that basis.

In 24-hour operation, in heats 274 to 301, two days, 45 hours and 40 minutes, running time, 36,500 pounds of metal, mostly 75¼ per cent Cu, 4½ per cent Sn, 14¼ per cent Pb, 3 per cent Sn alloy, and partly 84 per cent Cu, 6 per cent Sn, 10 per cent Pb alloy, was melted and poured at an average temperature of about 1,175° C. The power used by the arc, metered on the secondary side, was 4,159 kilowatt-hours, and that by the motor, 43. The power used by the arc, if metered on the primary side, would become 4,533, the total for arc and motor being 4,576. The heat balance is, then, approximately as follows:

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[a] Richards, J. W., Electric power required to melt metals: Trans. Am. Brass Founders' Assn., vol. 4, 1910, p. 95.

[b] Hansen, C. A., Electric melting of copper and brass: Trans. Am. Inst. Metals, vol. 6, 1912, p. 110.

Heat balance of rocking furnace on 24-hour schedule.

	Kilowatt hours.	Per cent.
Loss in transformer and leads	374	8
Motor	43	1
Loss in cooling water (48×7.5)	360	7½
Power usefully applied (theoretical), 36,500 pounds melted at 8 kilowatt-hours per 100 pounds	2,920	64
Balance left for shell radiation 48 hours, and door losses while charging 28 heats	889	19½
Total	4,576	100

Of the 4,159 kilowatt-hours actually supplied to the furnace itself, 2,920 were usefully applied, giving a 70 per cent efficiency on that basis.

If pouring delays were eliminated and the furnace was run at the rate of 18 heats of 1,350 pounds each in 24 hours, which is easily possible, the efficiency would rise to nearly 70 per cent calculated on the total power supplied to transformer, primary, and motor, and to about 75 per cent on that actually supplied to the furnace itself.

By increasing the capacity of the furnace to 1 ton or more, and by using the roof part for a refractory that would permit feeding power to the furnace at a slightly higher rate, an efficiency of at least 70 per cent, based on the total power supply, should be attained. That is, with the improvements being incorporated in the furnaces now building, the rocking type of furnace, if run with minimum delays in charging and pouring, is probably capable of reaching a power consumption figure of about 225 kilowatt-hours per ton of metal poured in melting red brass heated to about 1,150° C.

Comparison of melting costs with rocking electric furnace and with coke-fired furnaces.

[Melting cost comparison per ton of metal charged (labor cost is assumed to be the same in coke and electric melting and is omitted). Metal heated to 1,160° C. Conditions as at Michigan Smelting & Refining Co. plant.]

COKE-FIRED FURNACES.

	Normal cost.	Present cost.
Coke	$1.20	$2.00
Crucibles	1.40	12.50
Total	2.60	14.50

Electric Furnace.

	10-hour day.	24-hour day.
Power	\$3.40 [a]	\$2.65 [b]
Interest and depreciation	1.50	1.00
Electrodes	.80	.80
Linings	.40	.40
Heating ladles	.25	.25
Incidentals	.25	.25
Total	6.60	5.35
Credit 1.5 per cent, or 30 pounds, metal saved over coke-fired furnaces, at 15 cents	4.50	4.50
Total	2.10	1.20

Calculated saving:

10-hour electric melting over coke melting, present conditions, \$14.50 − \$2.10 = \$12.40.

24-hour electric melting over coke melting, present conditions, \$14.50 − \$0.85 = \$13.65.

10-hour electric melting over coke melting, normal conditions, \$2.60 − \$2.10 = \$0.50.

24-hour electric melting over coke melting, normal conditions, \$2.60 — \$0.85 = \$1.75.

POWER CONSUMPTION IN RELATION TO FUEL SUPPLY.

An average of 33 pounds of coke is required to melt 100 pounds of metallic charge in the Michigan Smelting & Refining Co.'s practice, using the large No. 250 crucibles, or at 13,000 B. t. u. per pound of coke, 429,000 B. t. u. per 100 pounds of metallic charge or 8,580,000 B. t. u. per ton is required. This is good practice for natural-draft crucible furnaces. One rolling mill figures that to melt one pound of 70:30 cartridge brass 5,460 B. t. u. are required, or 10,920,000 B. t. u. per ton, when the fuel used is about 90 per cent anthracite coal and 10 per cent coke.

According to Dow[c] a modern central-station steam power plant can produce 1 kilowatt-hour from 20,000 B. t. u. (bituminous coal), and 80 per cent of the power produced can be delivered at the customer's terminals. That is, it takes 25,000 B. t. u. to deliver 1 kilowatt-hour to the high-tension side of the customer's transformer.

In a five-day test, with 10-hour operation, the rocking furnace used 327 kilowatt-hours, primary meter, per ton of charge, corresponding to 8,175,000 B. t. u. In a four-day test, with 24-hour operation, the furnace used 264 kilowatt-hours per ton of charge, corresponding to 6,560,000 B. t. u.

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[a] 340 kilowatt-hours, metered on primary, at 1 cent per kilowatt-hour.

[b] 265 kilowatt-hours, metered on primary, at 1 cent.

[c] Dow, A., The production of electricity by steam power, Trans. Am. Electrochem. Soc., vol. 32, 1917, p. 352.

Taking 564,000 B. t. u. (160 kilowatt-hours) as the theoretical amount required to melt a ton of brass, the coke-fired furnaces at 8,580,000 B. t. u. are giving about 6.6 per cent efficiency. The generation of electric power from coal at 25,000 B. t. u. per kilowatt-hour, where the theoretical requirement is only 3,400 B. t. u., gives 13.6 per cent efficiency. The efficiency of the rocking furnace in the five-day test (10-hour operation) was 49 per cent, so that the over-all efficiency, after conversion of coal into electric power, is about 6.65 per cent. In the four-day test (24-hour operation) the efficiency was 61 per cent and the over-all efficiency was 8.27 per cent. The efficiency of the coke-fired furnaces in 24-hour operation would not be more than 7.5 per cent. A similar comparison of open-flame oil furnaces and of the electric furnace using power generated by oil engines would show about the same actual fuel consumption per ton in each.

Hence, on a B. t. u. basis, the use of electric power for melting brass in the rocking furnace does not require the ultimate consumption of any more fuel than natural-draft coke fires. Where hydroelectric power is available, no fuel is needed for the electric furnace.

Therefore the use of the electric furnace has no drawback compared with coke-fired furnaces as regards the use and transportation of fuel and has the advantages of eliminating crucibles, decreasing metal losses, and not requiring operators of as great muscular ability. These factors are of especial importance under the conditions brought about by the war.

It is not enough to know that the rocking furnace, under such conditions as obtain at the plant where it was tested, is capable of reduced melting costs over coke-fired furnaces, but other fuel-fired furnaces and other electric furnaces should be compared, though space is lacking to give detailed comparison here.

Open-flame oil furnaces work well on alloys low in zinc or lead and eliminate crucible costs. On true bronzes, with charges containing few borings, the melting costs, considering the higher metal losses in the open-flame furnace, would be about the same as in the electric furnace operating 10 hours daily. With alloys higher in zinc or lead, or with large amounts of borings, the metal losses in the open-flame furnace will probably throw the balance in favor of the electric, even with the low labor cost of the former.

In comparison with other electric brass furnaces ready for commercial use, the rocking type appears to have a flexibility superior to many types and second to none; that is, it can melt a wide range of alloys, in large or small charges, permit making successive heats of different alloys, and will run on a 10-hour day schedule without requiring night heating, as well as on a 24-hour schedule. The metal losses will be as low for a given alloy and charge as those of any other electric furnace, and for alloys containing volatile metals the losses will be lower than with direct-arc or unrocked indirect-arc furnaces.

The cost of refractories and electrodes will probably be no greater than those working under good practice for other electric furnaces. On the score of low power consumption the rocking furnace will show, for a given size of furnace and length of working-day, far better results than the furnaces in which heating is mainly by radiation from the roof, and rather better than the results that can be gotten with direct-arc or stationary indirect-arc furnaces. The power consumption will be somewhat higher than in the vertical-ring induction furnaces.

In sharp control of temperature and in thorough mixing of the metal the rocking type is equaled by the vertical-ring induction furnace, but no other type approaches it in those respects.

The first cost of the rocking furnace in a given size should compare favorably with the prices of the other types on the market, although, as with all electric furnaces, a large capital outlay is required on account of the high first cost as compared with that of fuel-fired furnaces. This initial cost, at least under present conditions, will be promptly repaid by the savings the furnace will make.

The disadvantages of the rocking type of furnace are as follows: Unless the furnace is made in capacities of considerably more than 1 ton, a single-phase arc is practically required, as there is scarcely room enough for two pairs of electrodes to enter through the ends of the furnace and still give convenient clearance everywhere. A single-phase load of the wattage needed, particularly an arc load, which at times fluctuates rapidly, may not be acceptable to the central station. This is no drawback in Detroit, nor would it be in most cities or large manufacturing towns, but in localities where the power circuit is of small capacity, it might bar the furnace from use.

The attendant must watch the furnace rather closely in order to adjust the angle of rocking to the progress of the heat; also, he must exercise some judgment in this adjustment. The electrodes may be broken from rocking the furnace too far while the charge is still solid, and, on the other hand, the angle of rocking should be kept as large as possible in order to keep the power consumption down and increase the life of the lining. A more refractory roof part may be expected to make such constant care less essential, though still desirable. The contacts on the rocking-control mechanism must be kept clean, and the bearings of the furnace rollers and gears must be kept lubricated.

Relining is a trifle more difficult when the roof part does fail than in a furnace with a detachable roof which can be promptly replaced with a spare roof, for the furnace must be cooled enough to let the mason go inside. Hence, the use of a high-grade refractory, such as zirkite, in the roof and upper halves of the ends, may be desirable in this type of furnace, the high initial expense being repaid by less frequent need for repairs and fewer interruptions of service. When large repairs to the lining are required, time would be saved if a crane of sufficient lifting capacity were available to turn the furnace on end, so it could be lined like a pit furnace.

These disadvantages all spring from the necessary design of a rocking type of furnace, and would appear to be overbalanced by the advantages of accurate temperature control, thorough mixing of the charge, low metal losses, applicability to alloys high in zinc, and lowered power consumption, which the rocking type has as compared with an unrocked indirect-arc furnace.

The rocking furnace, then, on the basis of tests in which 3,500,000 pounds of metal was melted, seems to deserve consideration in comparison with fuel-fired furnaces and with other types of electric furnaces. There are many plants where fuel-fired furnaces or other electric furnaces may meet local conditions better than the rocking furnace, but it would seem that the plants where it would meet local conditions more satisfactorily than other furnaces are numerous enough to make further development of the rocking type and more exact determination of its ability in comparison with other furnaces desirable.

FURTHER IMPROVEMENT AND DEVELOPMENT OF THE ROCKING FURNACE.

After the results of the tests recorded herein had been tabulated and studied the representatives of the Bureau of Mines and those of the Detroit Edison Co. revised the design of the furnace. The chief changes made are increasing the diameter of the hearth to 45 inches, instead of 36 inches, to bring the capacity of the furnace to 1 ton, and, of course, increasing the power input proportionally to the increase in weight of charge; slightly enlarging the door to facilitate charging; altering the electrode holders and the support for the slide to allow more rapid and convenient handling; lengthening the travel of the holder in order to permit drawing the electrodes farther back while charging; using a graphite sleeve or a granular packing to prevent sticking of the electrodes; and trying zerkite brick for the upper half of the inner course of the lining.

Two furnaces of the improved design are now under construction for the C. B. Bohn Foundry Co., of Detroit, which plans to use them in making munition castings. The original furnace after the addition of graphite sleeves about the electrodes is now (May, 1918) being used for regular production by the Michigan Smelting & Refining Co., and four furnaces of the improved design are being built for this firm. Also, the Aluminum Castings Co. has ordered four furnaces of this type and is contemplating the installation of two additional furnaces.

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